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RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

A BRIEF INVESTIGATION OF THE
HYDRODYNAMIC CHARACTERISTICS OF A 1/13.33-SCALE
POWERED DYNAMIC MODEL OF A PRELIMINARY DESIGN OF
THE MARTIN XP6M-1 FLYING BOAT

TED NO. NACA DE-385

By Ulysse J. Blanchard

Langley Aeronautical Laboratory
Langley Field, Va.

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LANGLEY AERONAUTICAL LABORATORY
LANGLEY FIELD, VIRGINIA



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SUMMARY

The hydrodynamic characteristics of a preliminary design of the Martin XP6M-1 flying boat have been determined. Longitudinal stability during take-off and landing, resistance of the complete model, and behavior during taxiing and landing in rough water are presented.

INTRODUCTION

An investigation of the hydrodynamic characteristics of a powered dynamic model of the Martin XP6M-1 seaplane was requested by the Bureau of Aeronautics and the Glenn L. Martin Company. Tank tests have been made of the basic model and of such modifications as were required for a brief but general appraisal of the hydrodynamic characteristics in smooth and rough water. Inasmuch as a need for changes in hull lines was apparent early in the investigation, the tests and modifications were limited to those items of particular interest to the designer. Since the model did not represent the final configuration, detailed information on most of the hydrodynamic characteristics was not obtained. The data are presented without detailed analysis or discussion.

Mr. Eugene Handler of the Glenn L. Martin Company witnessed most of the tests.

A redacted signature, appearing as a solid black horizontal bar.

SYMBOLS

C_L	aerodynamic lift coefficient, $\frac{L}{\frac{1}{2}\rho V^2 S}$
C_m	aerodynamic pitching-moment coefficient, $\frac{M}{\frac{1}{2}\rho V^2 S \bar{c}}$
$\bar{c}$	mean aerodynamic chord, ft
L	total aerodynamic lift, lb
M	aerodynamic pitching moment, ft-lb
S	wing area, sq ft
V	carriage speed, ft/sec
δ_f	flap deflection, deg
δ_s	stabilizer deflection, deg
ρ	density of air, slugs/cu ft
τ	trim (angle between forebody keel at step and horizontal), deg
τ_L	landing trim, deg

DESCRIPTION OF MODEL

The 1/13.33-scale powered dynamic model (Langley tank model 314) is shown in figures 1 and 2. The general arrangement of the seaplane is shown in figure 3. The basic model was supplied by the David Taylor Model Basin, Navy Department. The hull was constructed of Fiberglas and plastic, and was molded from an existing wooden wind-tunnel model. Details of construction were generally similar to those currently used for dynamic models.

Jet power was simulated by compressed-air nozzles mounted in the nacelle ducts. Air was supplied to the jets through a flexible hose

from a control valve and manifold connected to high-pressure air bottles mounted on the towing carriage.

The flaps were attached to the wing by means of small cantilever springs. Strain gages on these springs were used to measure flap hinge moments.

The original wing-tip floats shown in figures 1 and 2 were removed for practically all tests prior to the final configuration. For the final configuration, the tip floats were modified as shown in figure 4. This modification, suggested by the Glenn L. Martin Company, was intended only to assure that necessary planing lift would be obtained.

The pitching moment of inertia of the model was 4.4 slug-feet². The ratio of elevator deflection to stabilizer deflection for the all-movable tail was 2 to 1.

The following configurations were investigated:

Model 314 (figs. 1 and 2) - This was the basic model modified by moving the wing forward and increasing the horizontal tail area according to information supplied by the Glenn L. Martin Company. Tests were made with clearance slots around the mine-carrier door as shown in figure 2, with dams in the slots at the step, and with the slots filled to form a smooth planing bottom.

Model 314A (fig. 5) - The width of the afterbody sections above the chines from the midlength of the afterbody to the sternpost was increased by means of an external fairing attached to the hull. The step was moved aft approximately 1/8 inch, which increased the depth of step at the keel to 0.08 inch (1.07 inches, full-scale). Dams were placed in the mine-carrier-door slots at the step.

Model 314B (fig. 6) - A 1/4-inch spray strip was added to the afterbody of model 314A and the external fairing above the chines was removed. The spray strips were located approximately at the point of maximum beam and extended from the rear end of the mine-carrier door to the sternpost. These strips were an addition to the existing chine strips of the basic afterbody and were faired into the hull at the forward end.

Model 314B-1 - The total width of the spray strip of model 314B (1/4-inch strip plus existing chine strips of the basic afterbody) was reduced to 1/4 inch over the entire length.

Model 314B-2 - The width of the spray strip was reduced to 1/8 inch over the entire length.

Model 314B-3 - The spray strips of model 314B-2 were removed. This model was similar to the basic model with the step moved aft and with slot dams.

Model 314C (fig. 7) - Wedges shaped to form longitudinal steps were installed on the forebody, inboard of the mine-carrier-door slots of model 314B-3.

Model 314D (fig. 8) - The afterbody sections of model 314C were revised to accommodate a new turret fairing. Modified tip floats as shown in figure 4 also were installed.

APPARATUS AND PROCEDURE

The investigation was made in Langley tank no. 1, which is described in reference 1. The apparatus and procedures generally used for testing dynamic models are described in references 2 and 3. A typical photograph of the model on the towing gear is shown in figure 9.

The aerodynamic lift and pitching moments were determined with the center of moments (pivot) located at 25 percent of the projected mean aerodynamic chord. The pivot height was adjusted for each trim so that the lowest point on the model was approximately 1/2 inch above the water. During tests with power, the static horizontal-thrust force was also measured for three values of manifold pressure. This procedure was used so that the pitching moment could be extrapolated to the full-thrust condition.

For the hydrodynamic tests, the model was free to trim and free to move vertically but restrained in roll and yaw. In order to prevent excessive yawing and possible damage to the model, additional restraint by means of a yoke mounted over the bow of the model was provided. In rough water the yoke was removed and approximately 5 feet of fore-and-aft freedom was provided to simulate correct motions in waves.

The hydrodynamic qualities were determined at the design gross load which corresponded to 160,000 pounds. The flaps were deflected 40° except during resistance tests where a deflection of 0° also was included for the range of speed in which the flaps were heavily wetted. The total resistance of the complete model was measured.

Take-offs were made at a constant acceleration of 3 feet per second per second. The thrust was not simulated but the pitching moment associated with full thrust was applied by means of a weight moment.

All smooth-water landings were made at a constant deceleration of 6 feet per second per second. The vertical allowable travel of the model for these landings was 21 inches.

In rough water, the initial landing approach was made at constant trims of 8° and 12° with the sternpost 8 inches above the static water level. After initial contact, the model was allowed vertical movement of 26 inches. A deceleration of $7\frac{1}{2}$ feet per second per second was required in order to keep the model from striking the rear stop of the fore-and-aft gear. Landings were made in waves 2, 4, 6, and 8 feet in height (full-scale). To expediate the progress of the tests the model was not instrumented to measure accelerations.

Movie cameras mounted forward of the bow and above the model recorded general behavior. Underwater photographs were taken when details of flow over the bottom of the hull were of particular interest. Slide-wire pickups were used to obtain time histories of the trim, the rise of the center of gravity, and the fore-and-aft position of the model.

All test results have been converted to values corresponding to the full-scale seaplane.

RESULTS AND DISCUSSION

Aerodynamic

The effect of stabilizer deflection on the aerodynamic lift and pitching moment, power off, is shown in figure 10; and the effect of power, with a stabilizer deflection of -5° , is shown in figure 11. The variation of static-thrust moment with thrust is shown in figure 12. The latter plot was extrapolated to full thrust to obtain the thrust moment to be simulated in the take-off tests.

Hydrodynamic

Model 314.- During the initial runs of the basic model (model 314), a yawing and rolling oscillation was encountered at low speeds. This motion appeared to be associated with the flow of water over the after-deck of the wing-tip floats. Since the roll and yaw of the model was restrained by the towing staff in the roller cage, these motions are not representative of those for a free body. In order to avoid excessive loads on the model and towing gear caused by these motions, the

tip floats were removed before tests at higher speeds were made. The tip floats were not used again until model 314D was tested.

In the range of speed corresponding to 70 to 100 knots (full-scale), the basic model again showed a decided tendency to yaw. Underwater photographs, such as figure 13, indicated a heavy wetting of the afterbody behind the step while in the yawed condition, and spray observations and motion pictures indicated a heavy unsymmetrical flow at the stern. To avoid possible damage to the model and gear, the restraining yoke was installed at the bow to limit the amplitude of yaw.

In order to determine the probable cause of the directional instability at high speeds, tests were made with successive portions of the slots around the mine-carrier doors eliminated. It was found that the tendency to yaw did not appear if the longitudinal slots on the forebody were filled. Transverse dams in the slots at the step also were effective, although some instability occurred during take-off at high trims. The dams appear to have increased the hydrodynamic lift as evidenced by a decrease in wetted length when compared with that of the basic model in the unyawed condition (see fig. 14).

The trim limits of stability with the slots around the mine-carrier door open and filled are presented in figure 15(a). Very little data were obtained at high trims with the slots open because the trim was restrained by the friction of the bow yoke when the model yawed. At intermediate planing speeds, a region of mild instability, just above the lower limit, was noted. The extent of this region was not determined on the basic model. Motion pictures, however, indicated that, while this instability occurred, water from the main step intermittently struck the afterbody. This same instability was noted for all modifications.

The variation of trim during take-off is shown in figure 15(b). A typical time history of trim, rise, and speed during landing is presented in figure 15(c). The maximum variation of trim and rise and the number of skips during landing are presented in figure 15(d). The longitudinal instability at high speeds, apparent on both the take-off and landing, might be expected inasmuch as the upper trim limit (fig. 15(a)) is seen to approach the lower limit at a speed of approximately 125 knots.

During take-off, water from under the model flowed up the sides of the afterbody and wetted the deck just forward of the vertical tail. This flow started ahead of that portion of the afterbody having chines. Forebody spray struck the tips of the horizontal tail.

The effect of various slot configurations on the resistance and trim is shown in figure 15(e). With all the slots open, the apparent

discontinuity in the resistance curve appeared to be associated with the breaking of the flow of water from the sides of the rear portion of the afterbody. When deflected, the flaps were heavily wetted at hump speeds and the hump resistance was considerably greater than that with the flaps retracted.

Model 314A.- The variation of trim and resistance with speed for model 314A is presented in figure 16. The new fairing at the stern was heavily wetted and the flow of water over the sides of the afterbody apparently developed suction forces which caused the trim to increase at speeds above hump speed. Water over the deck of the model wetted the lower portion of the vertical tail. Tests of this model were discontinued because of increased violence of the directional instability at high speeds.

Models 314B, 314B-1, 314B-2, and 314B-3.- The variation in trim during take-off for model 314B with the various widths of spray strips is shown in figure 17. A comparison of figures 17(a), 17(b), and 17(c) with figure 17(d) (spray strips removed) indicates that the spray strips tended to reduce the porpoising near getaway. The spray strips effectively reduced the flow of water up the sides of the afterbody.

A comparison of take-offs of model 314B-3 (fig. 17(d)) with those for the basic model (fig. 15(b)) indicates that there was a slight reduction in porpoising near getaway when the step was moved aft.

A small quantity of flap-hinge-moment data was obtained with model 314B-3 and is presented in table I. The data cover the hump region where the flaps, when deflected, appeared to be planing on the bow wave.

Model 314C.- The trim limits of stability of model 314C are presented in figure 18(a). An instability at intermediate trims, between the conventional upper and lower trim limits, was previously noted for the basic model and was defined in more detail for this model. Porpoising encountered in this region, during the constant-speed runs, was of 2° and 3° amplitude and was not violent. During take-off this porpoising was encountered with the center of gravity at 36.5 percent mean aerodynamic chord and a stabilizer setting of -5° (see fig. 18(b)).

Typical time histories of the trim, rise, and speed and of the maximum amplitudes and number of skips during landing, are presented in figures 18(c) and 18(d), respectively. Comparison of the trim limits and smooth-water take-off and landing behavior of model 314C with those for the basic model indicates that a marked improvement in longitudinal stability was realized by use of the longitudinal steps.

The variation of resistance and trim with speed is presented in figure 18(e). The faired curves indicate the minimum total resistance that could be obtained at stable trims with the available trimming moments. At intermediate planing speeds, data were not obtained at lower trims because the model was porpoising in the intermediate unstable trim range shown in figure 18(a).

Model 314D.- The trim limits of stability and the variation in trim during take-off for model 314D are presented in figures 19(a) and 19(b). The variation in resistance and trim with speed is presented in figure 19(c). The effect of the modified tip floats on the resistance is also shown in figure 19(c). The oscillation of the model in the towing gear, noted in the earlier tests with the original tip floats, did not appear when the modified tip floats were used.

The power-off landings of model 314D in rough water indicated that light spray entered the jet intakes in 2-foot waves. Spray in the intakes was greatly increased in the higher waves. Water flowed over the bow and the windshield was heavily wetted in all waves investigated. The deck of the hull and the entire upper center section of the wing was wetted in 8-foot waves. Changes in rise and fore-and-aft position on the towing gear were large in 8-foot waves and the motions of the model were violent.

Low-speed taxiing in 8-foot waves indicated that the windshield and intakes were wetted. At taxiing speeds around 30 knots (full-scale), the entire fuselage and large areas of the wing were wetted by water flowing over, and thrown up by, the bow.

CONCLUDING REMARKS

Tests of the 1/13.33-scale model indicate that the directional instability at high forward speeds was eliminated by filling the longitudinal forebody slots around the mine-carrier door or by inserting dams in these slots at the step. Moving the step aft to obtain a depth of 1.07 inches (full-scale) at the keel had only a slight effect on the take-off stability. Porpoising on take-off and landing was appreciably reduced by longitudinal steps on the forebody. The yawing and rolling

motions encountered at low speeds when tip floats were used did not appear with the tip floats modified to produce greater lift.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., October 21, 1953.

Ulysse J. Blanchard
Ulysse J. Blanchard
Aeronautical Research Scientist

Approved: *John B. Parkinson*
John B. Parkinson
Chief of Hydrodynamics Division

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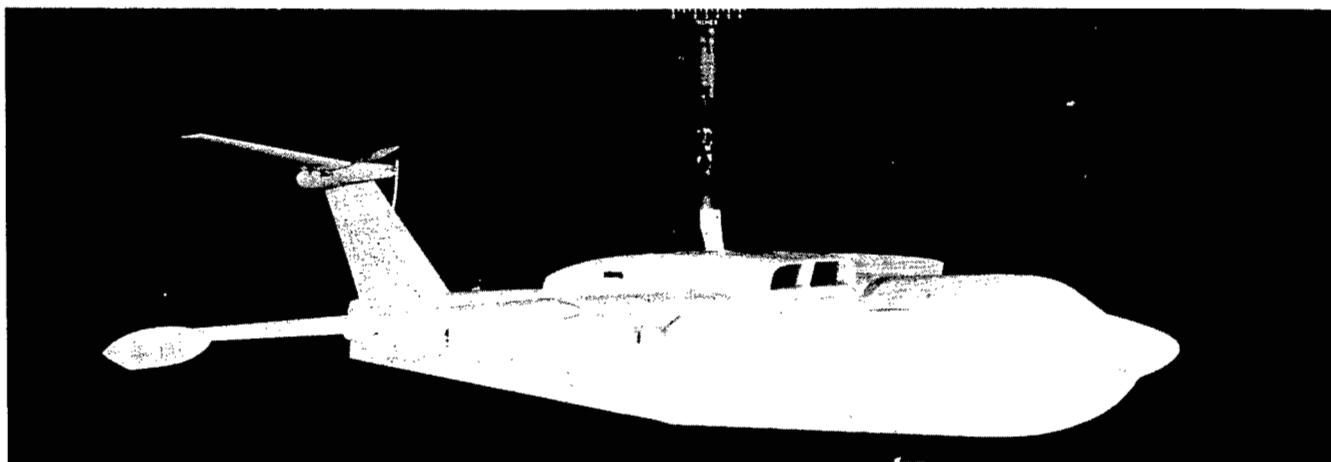
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1. Truscott, Starr: The Enlarged N.A.C.A. Tank, and Some of Its Work. NACA TM 918, 1939.
2. Olson, Roland E., and Land, Norman S.: Methods Used in the NACA Tank for the Investigation of the Longitudinal-Stability Characteristics of Models of Flying Boats. NACA Rep. 753, 1943. (Supersedes NACA WR L-409.)
3. Carter, Arthur W.: Effect of Hull Length-Beam Ratio on the Hydrodynamic Characteristics of Flying Boats in Waves. NACA TN 1782, 1949.

TABLE I.- FLAP-HINGE-MOMENT DATA DURING TAKE-OFF FOR
LANGLEY TANK MODEL 314B-3

[Center of gravity, 36.5 percent M.A.C.]

Run	δ_s , deg	Speed, knots	Trim, deg	Rise, ft	Hinge moment, ft-lb
1	-9	30.73	4.6	-5.9	0
		34.62	5.0	-5.8	18,022
		51.07	8.9	-3.7	17,759
		64.92	9.0	-2.2	0
2	-9	32.46	4.8	-5.8	0
		36.79	5.3	-5.6	21,442
		50.85	8.7	-3.9	18,811
		63.84	11.0	-2.2	0
3	-9	32.46	4.5	-6.0	0
		34.62	5.0	-5.8	17,759
		37.87	5.5	-5.6	19,601
		51.94	8.3	-3.6	17,101
		62.76	9.0	-2.3	0



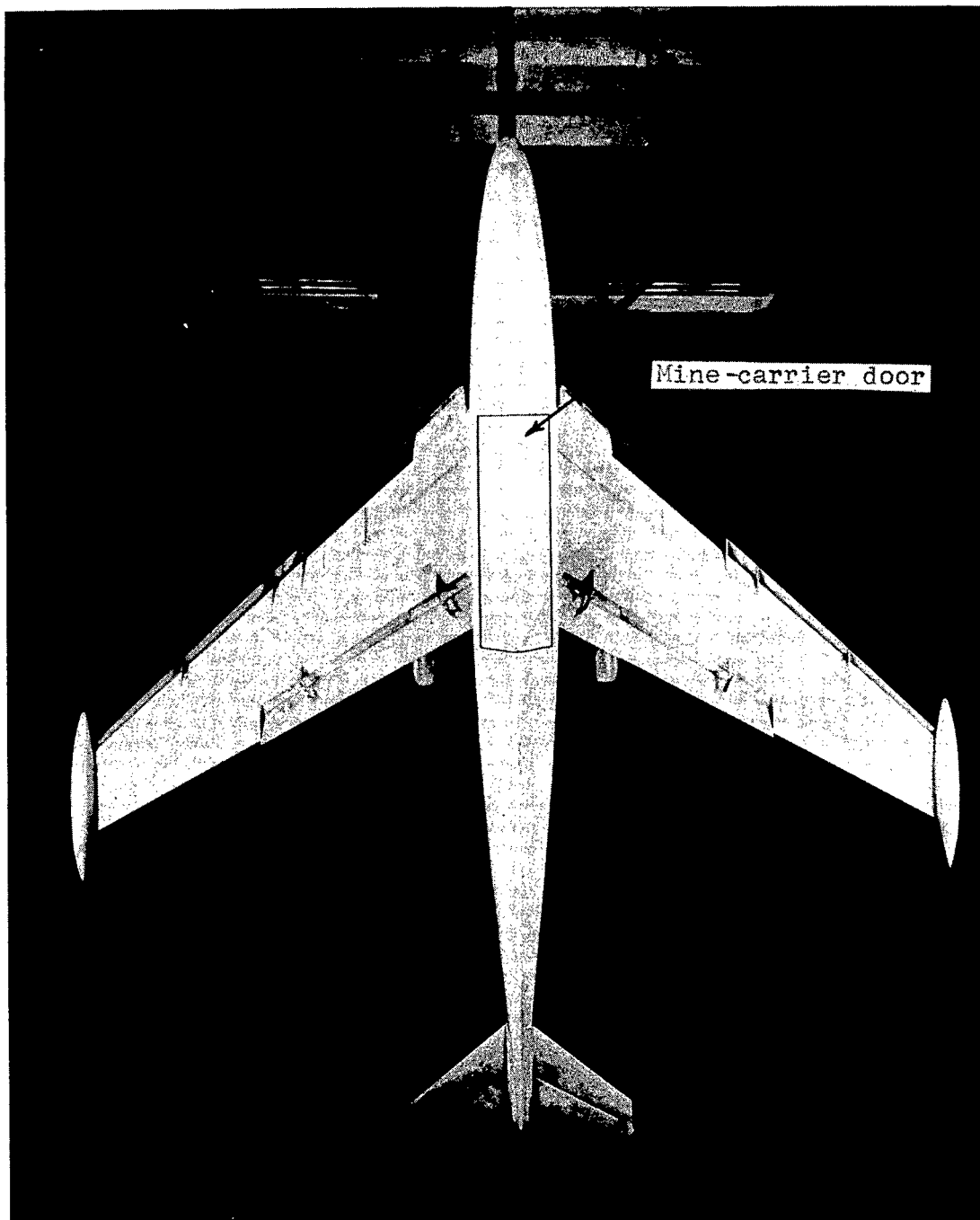
Three-quarter front view



Profile view

Figure 1.- Langley tank model 314.

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Figure 2.- Langley tank model 314. Bottom view showing mine-carrier door.

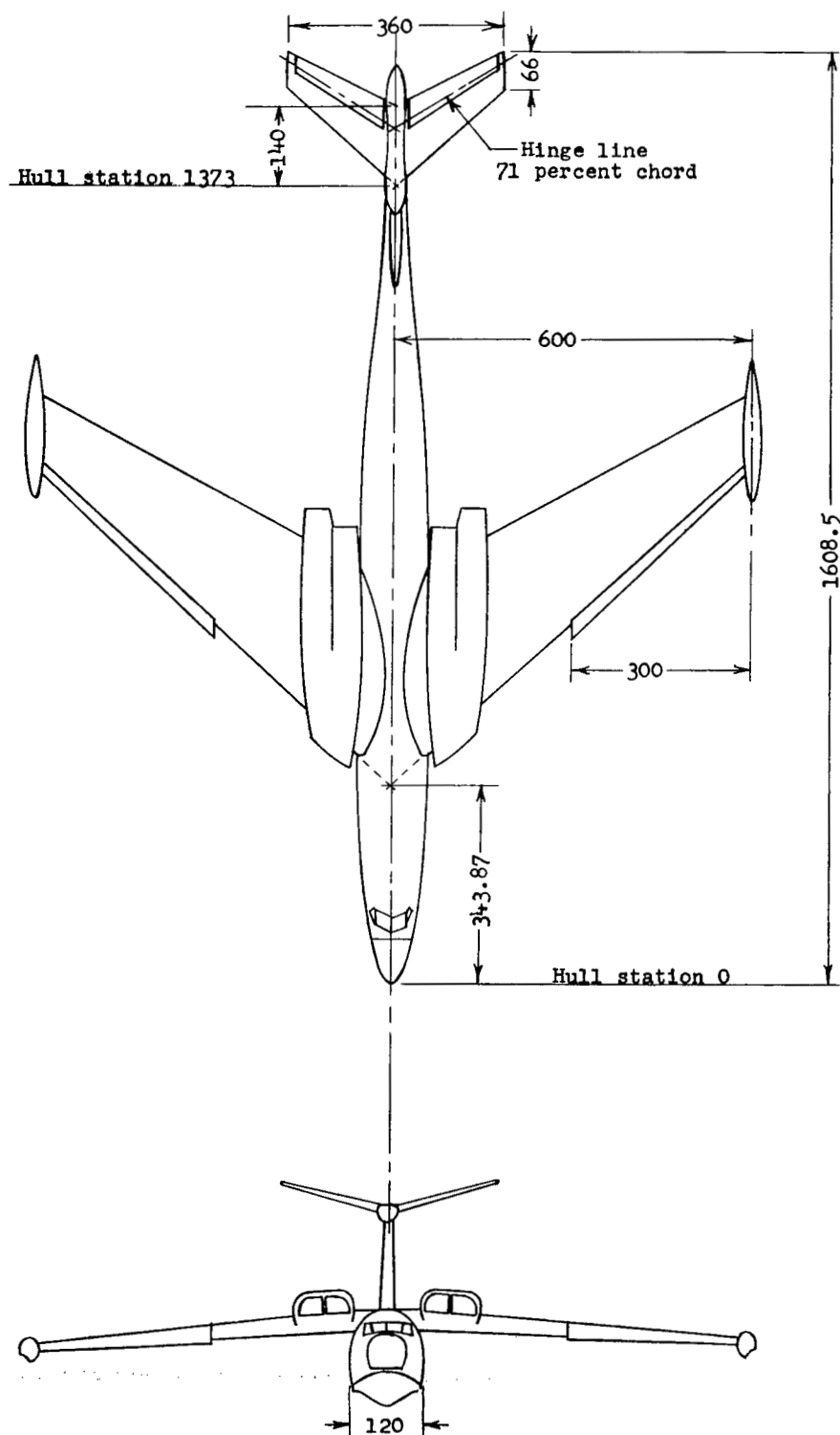
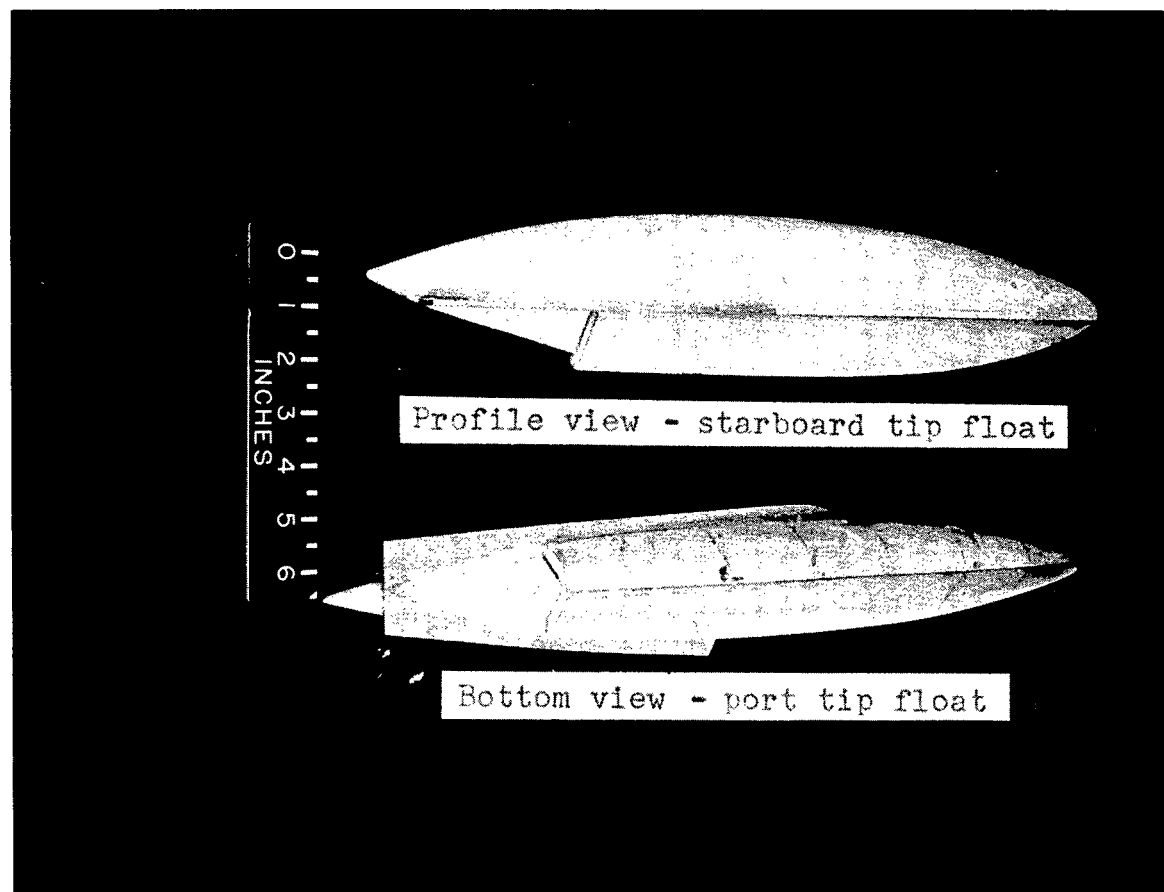


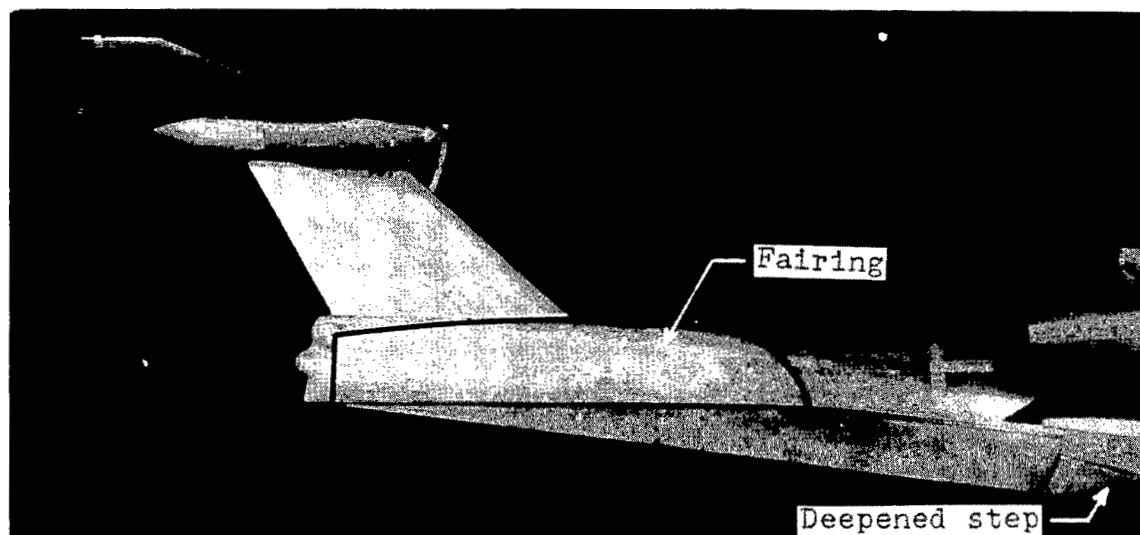
Figure 3.- General arrangement of the Martin XP6M-1 flying boat.
(Dimensions are in inches.)



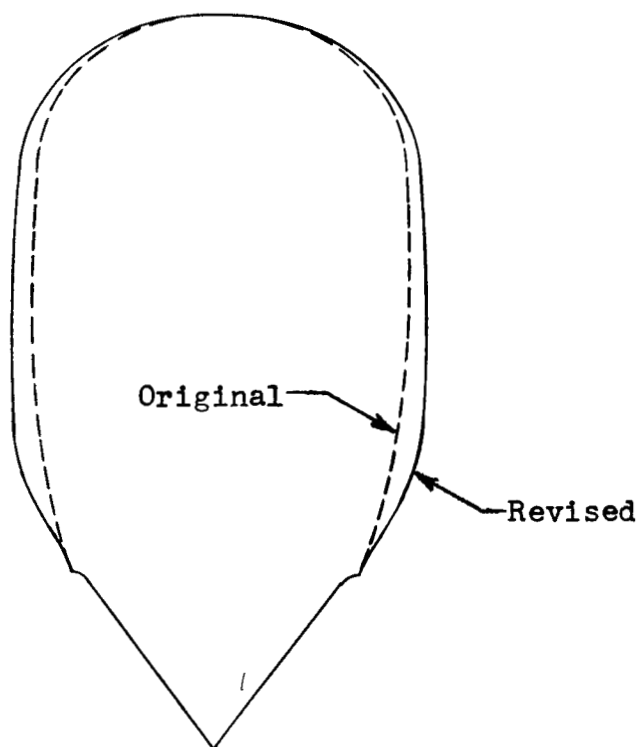
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Figure 4.- Modified tip float for Langley tank model 314.

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Detail of afterbody fairing

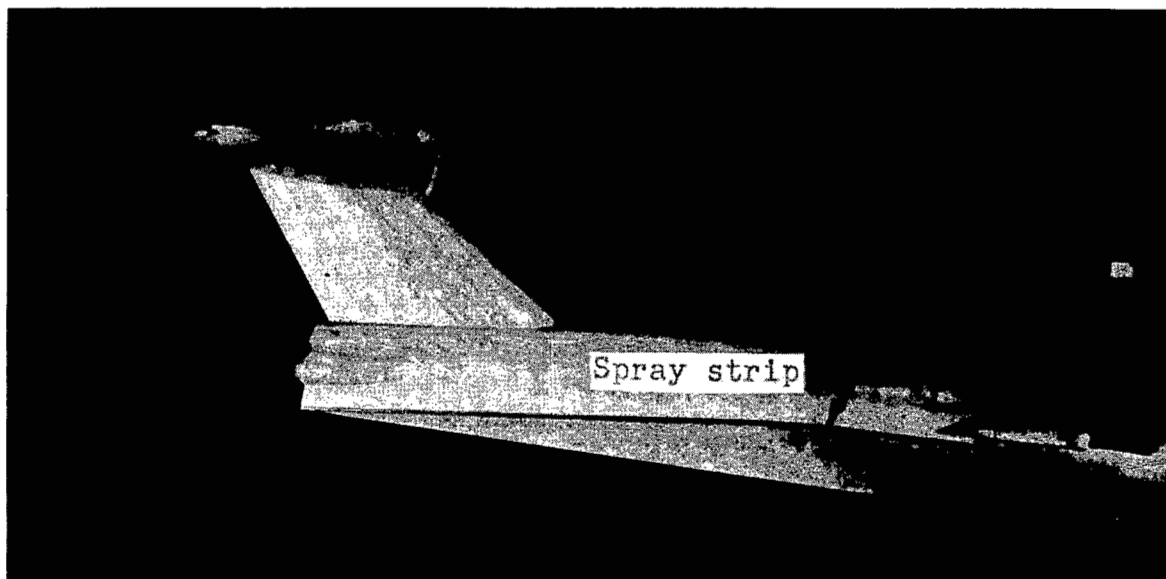


Typical afterbody section

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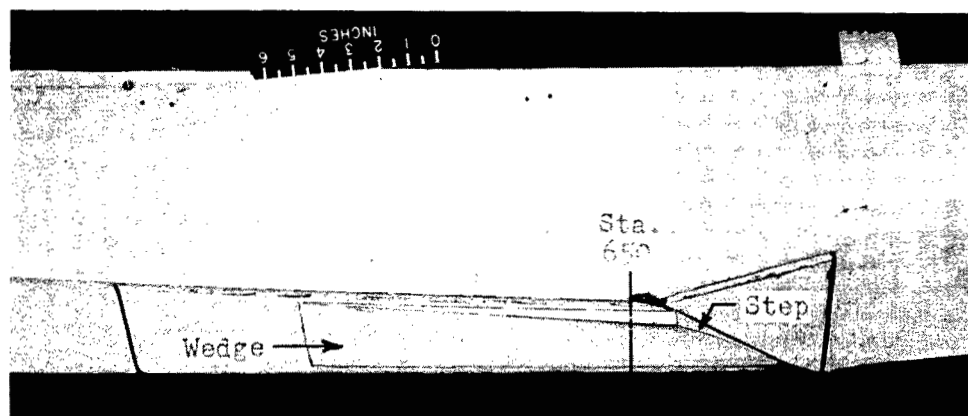
Figure 5.- Langley tank model 314A showing revised afterbody fairing and deepened step.

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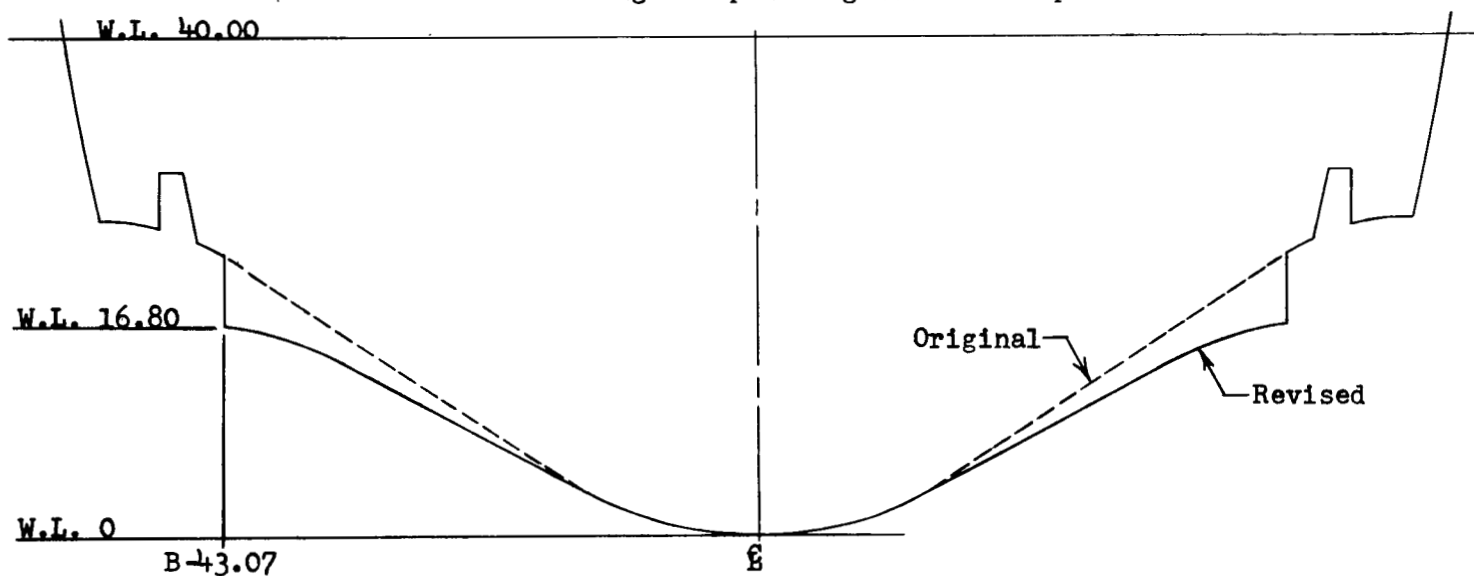


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Figure 6.- Langley tank model 314B with afterbody spray strip.



Detail of wedge-shaped longitudinal step

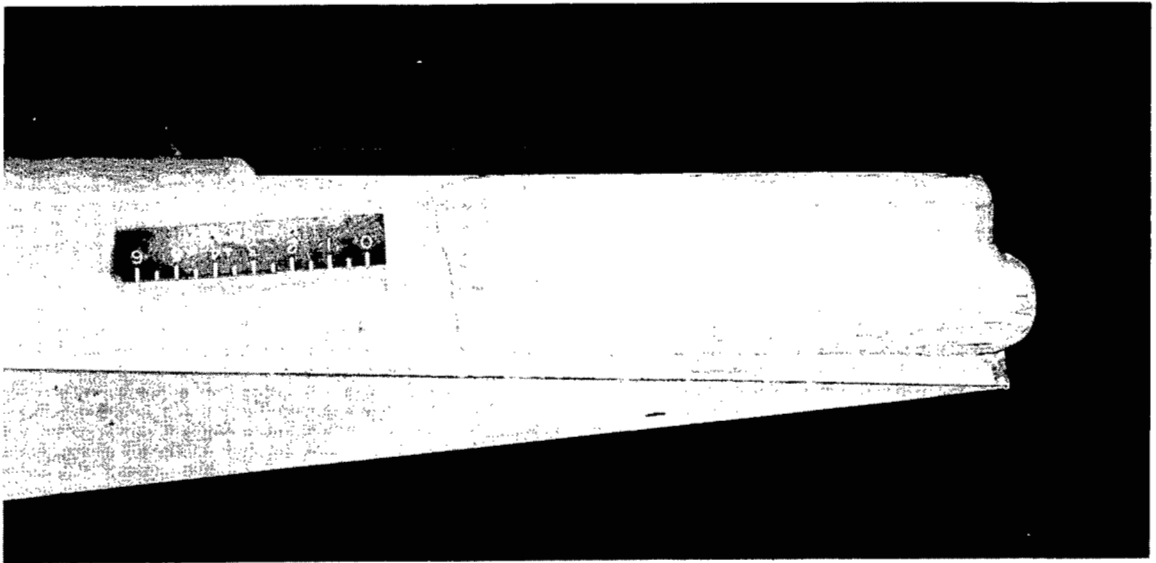


Cross section of hull bottom - station 650

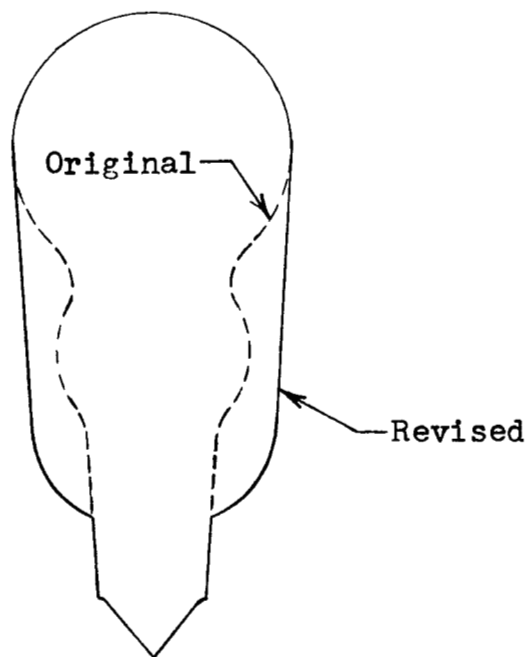
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Figure 7.- Langley tank model 314C with wedge to form longitudinal step.

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Detail of turret fairing

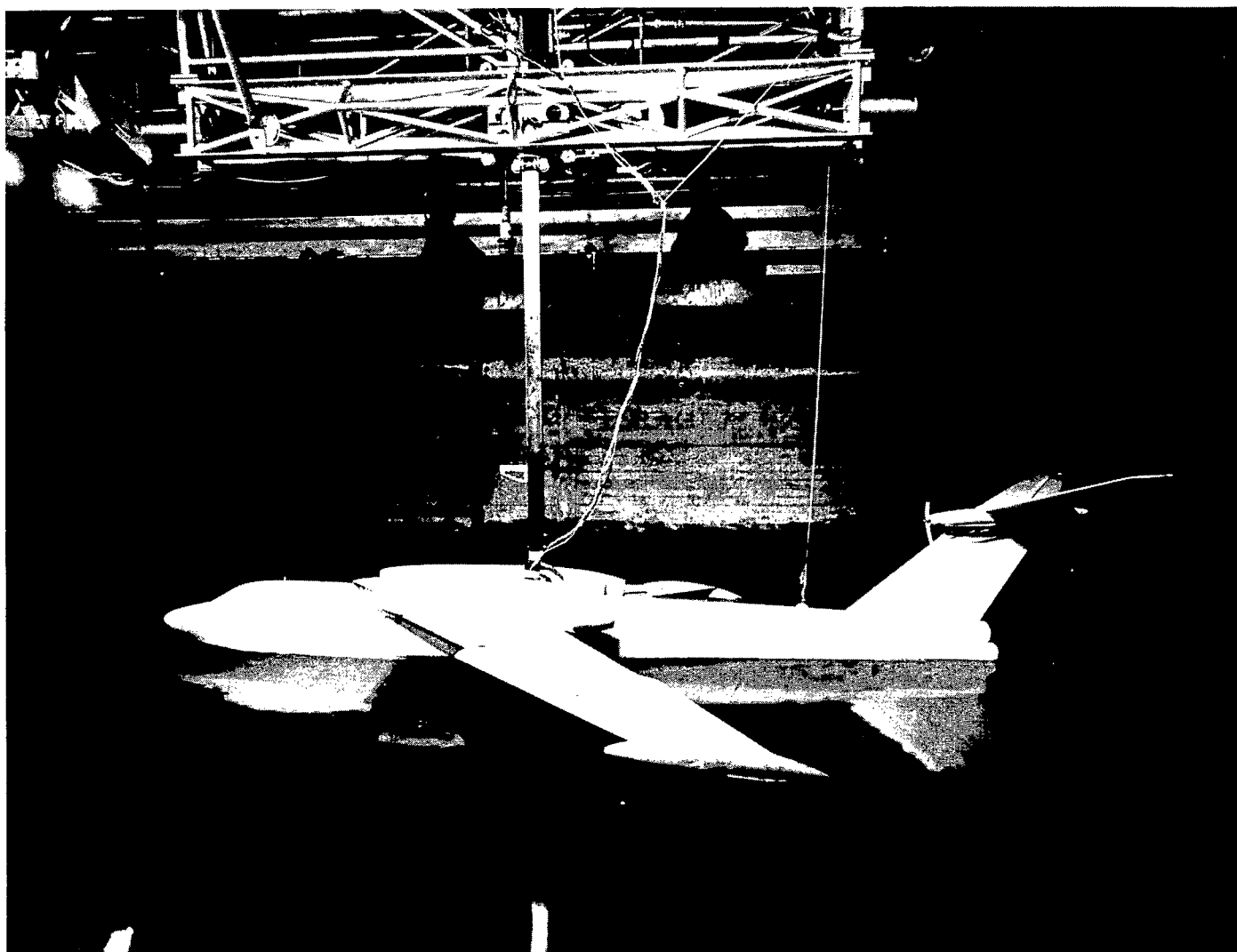


Typical afterbody section

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Figure 8.- Langley tank model 314D with revised turret fairing.

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Figure 9.- Setup of Langley tank model 314D on towing apparatus.

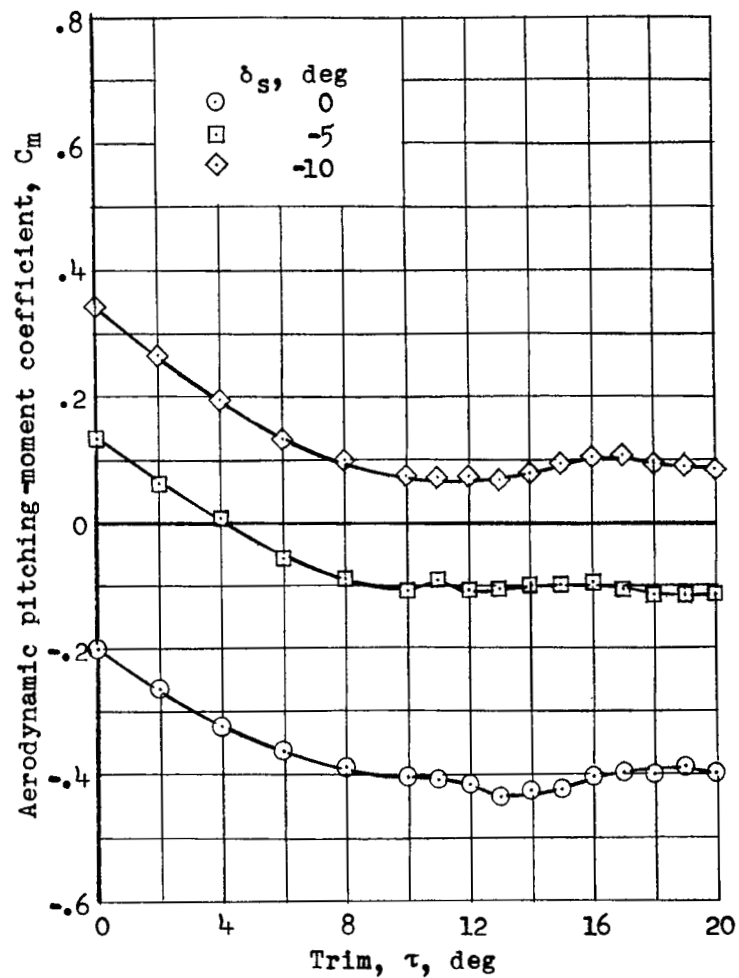
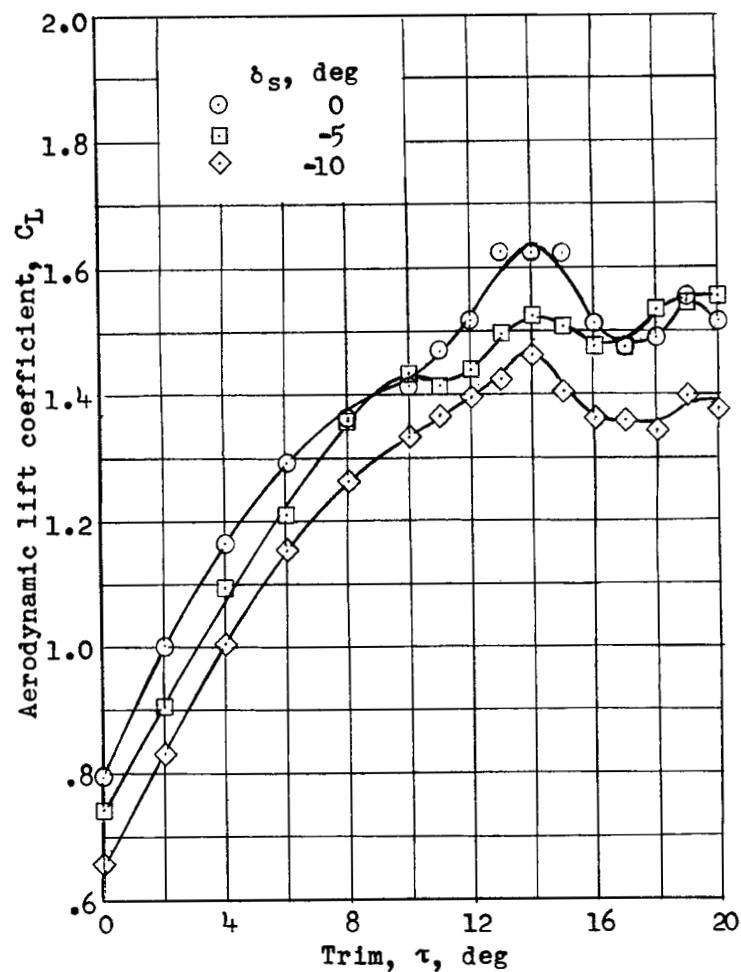


Figure 10.- Effect of stabilizer setting on aerodynamic lift and pitching-moment coefficients. Power off; Langley tank model 314.

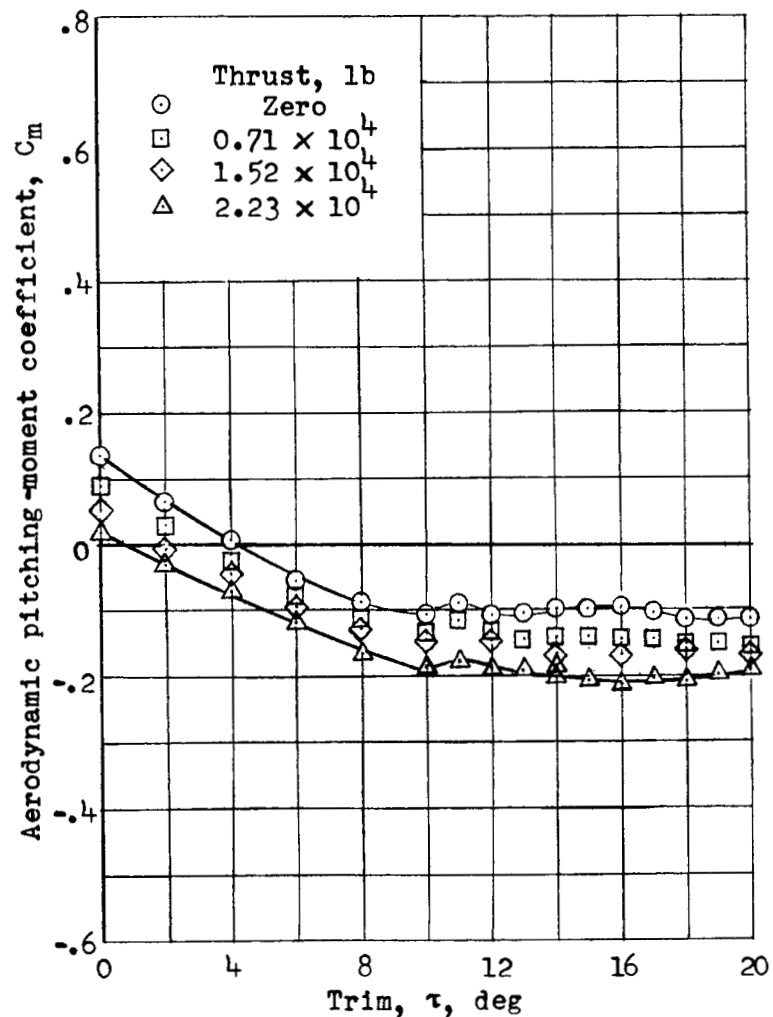
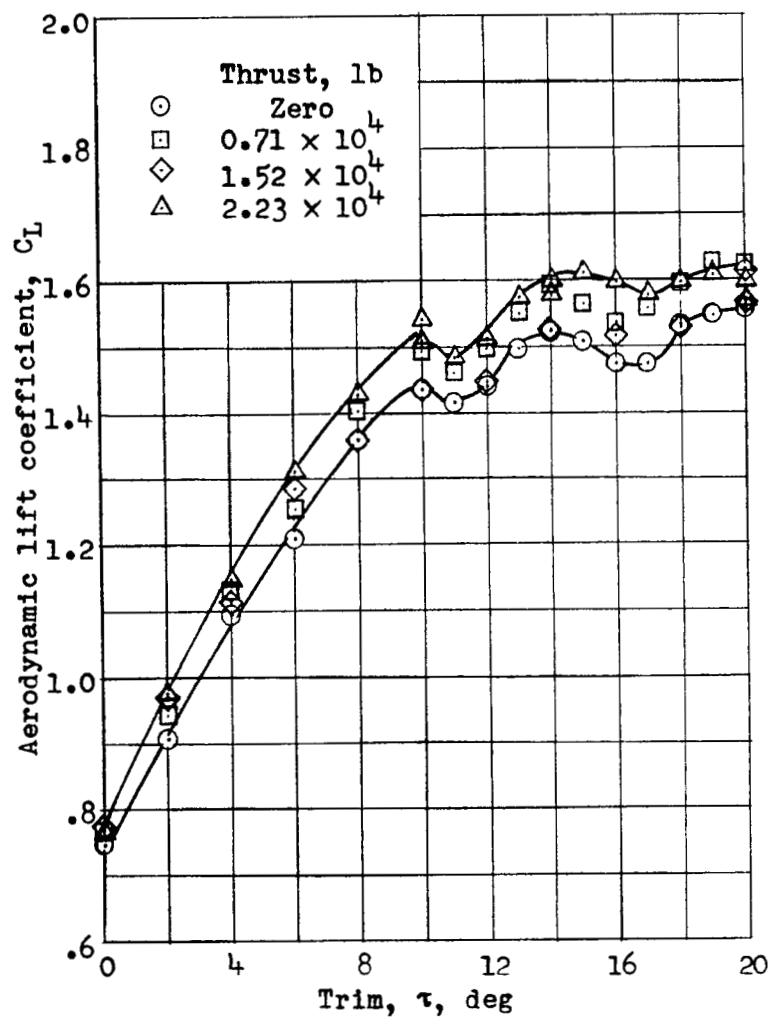


Figure 11.- Effect of power-on aerodynamic lift and pitching-moment coefficients. Stabilizer setting, -5° ; Langley tank model 314.

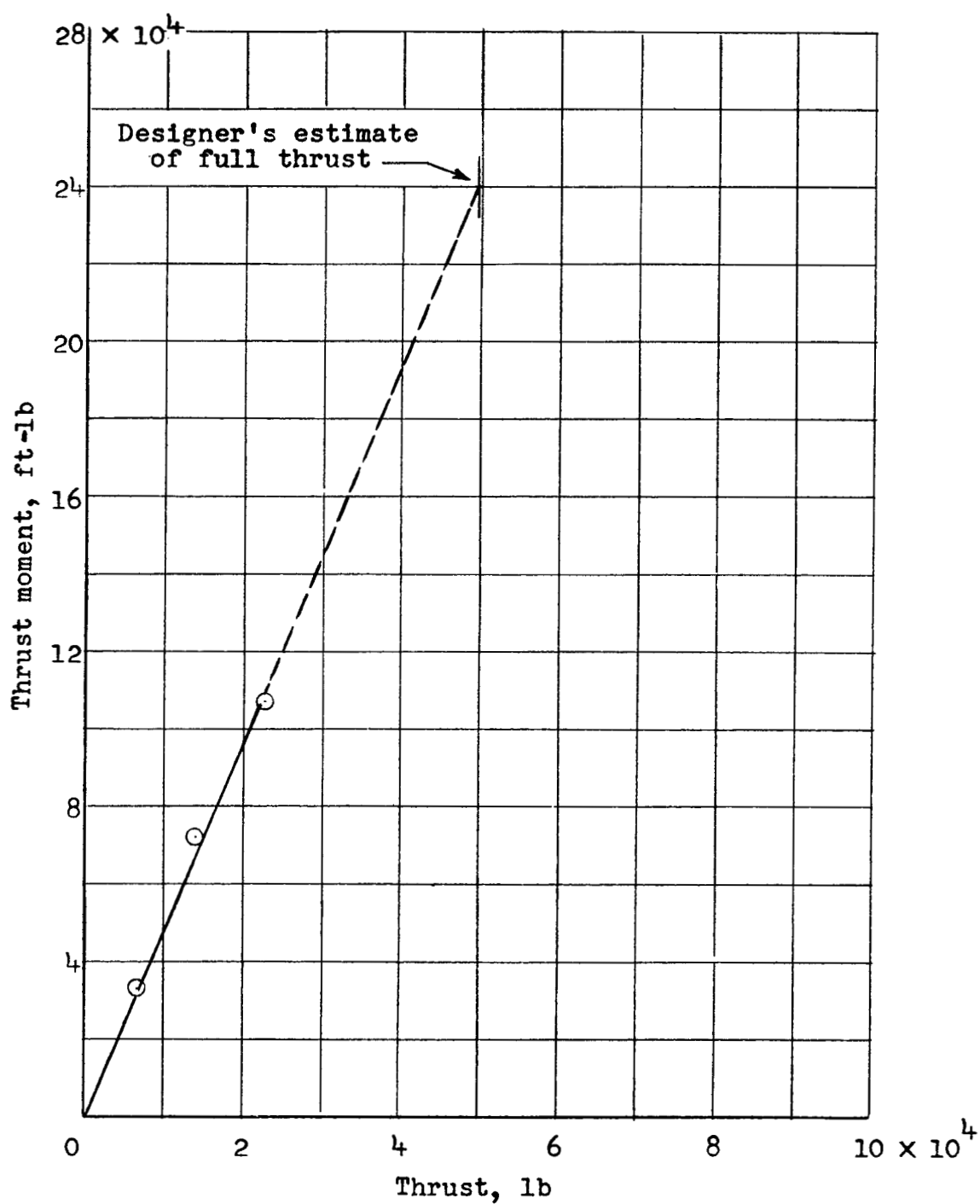
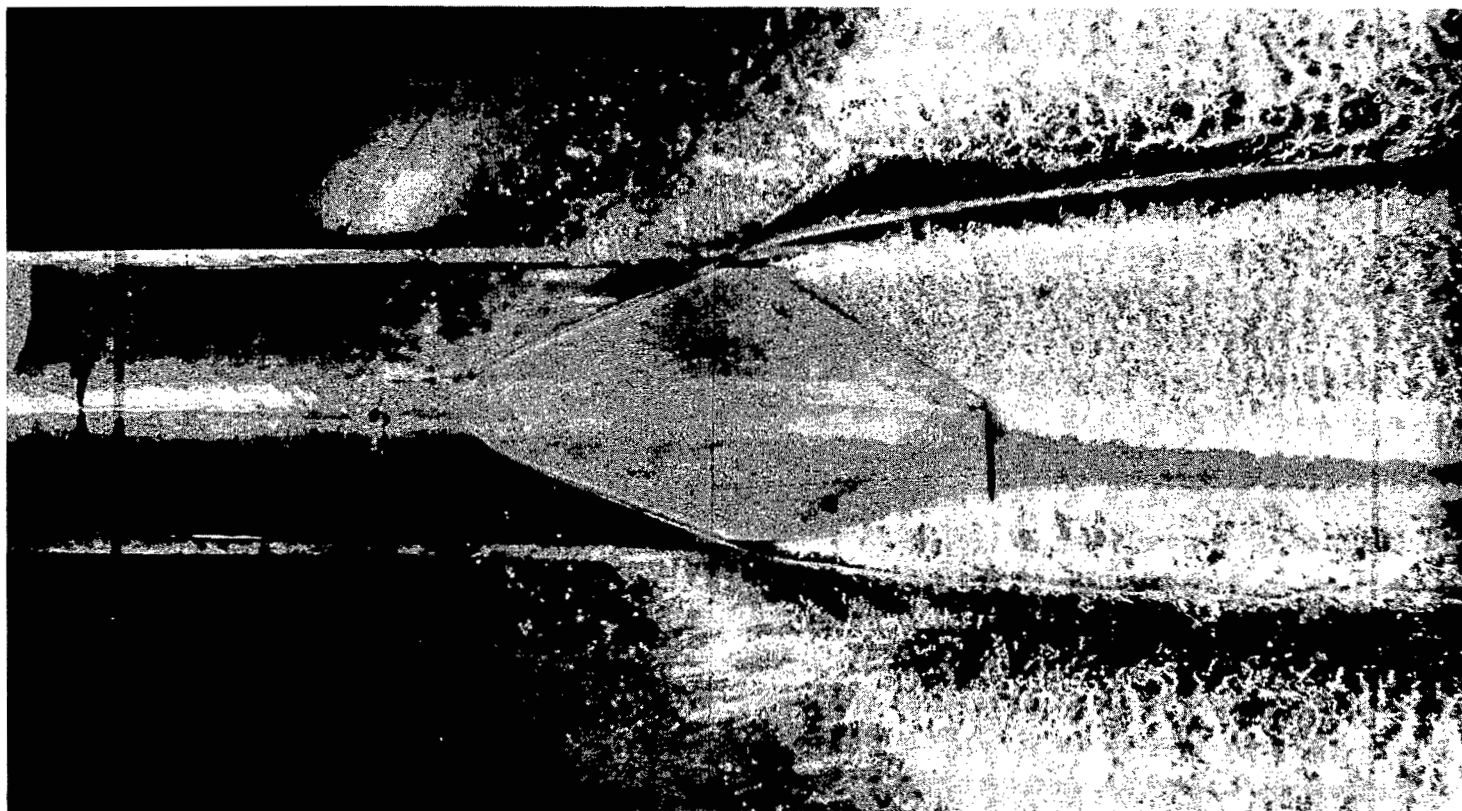
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Figure 12.- Variation of static-thrust moment with thrust. Langley tank model 314.

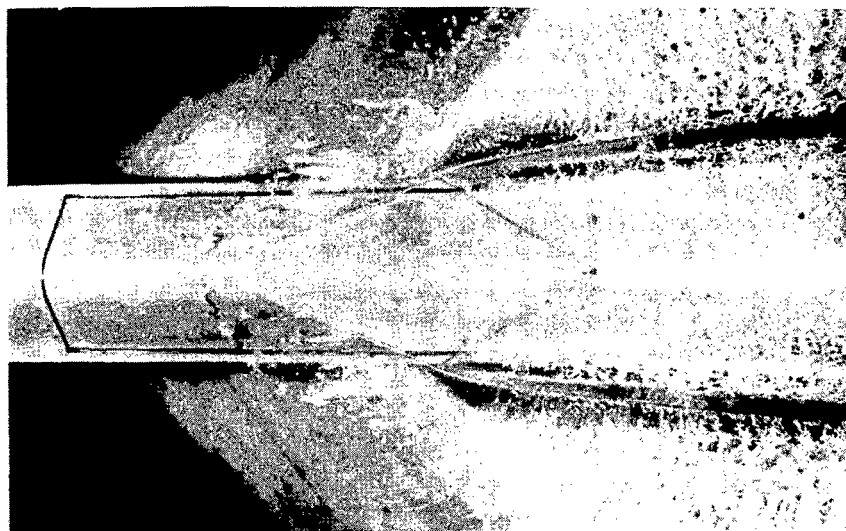
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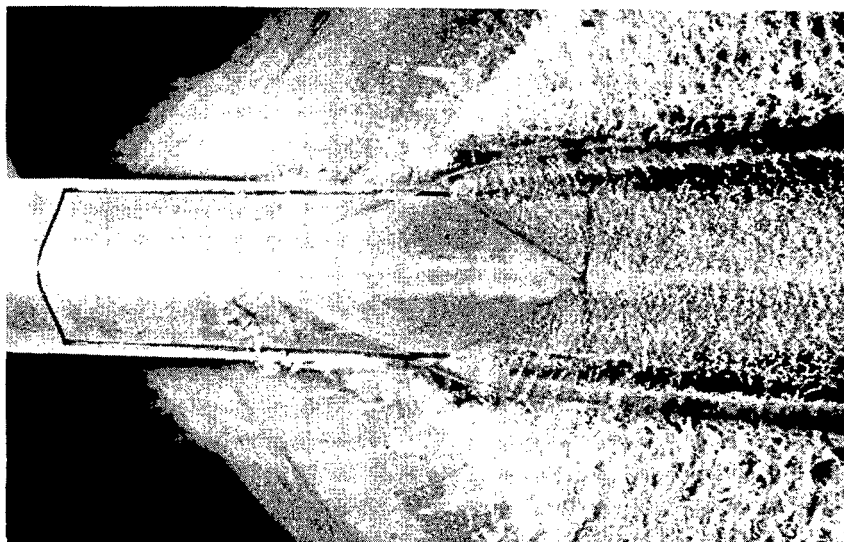


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Figure 13.- Underwater photograph of Langley tank model 314. Model yawed to right; speed, 93 knots (full-scale); trim, 8.6° .



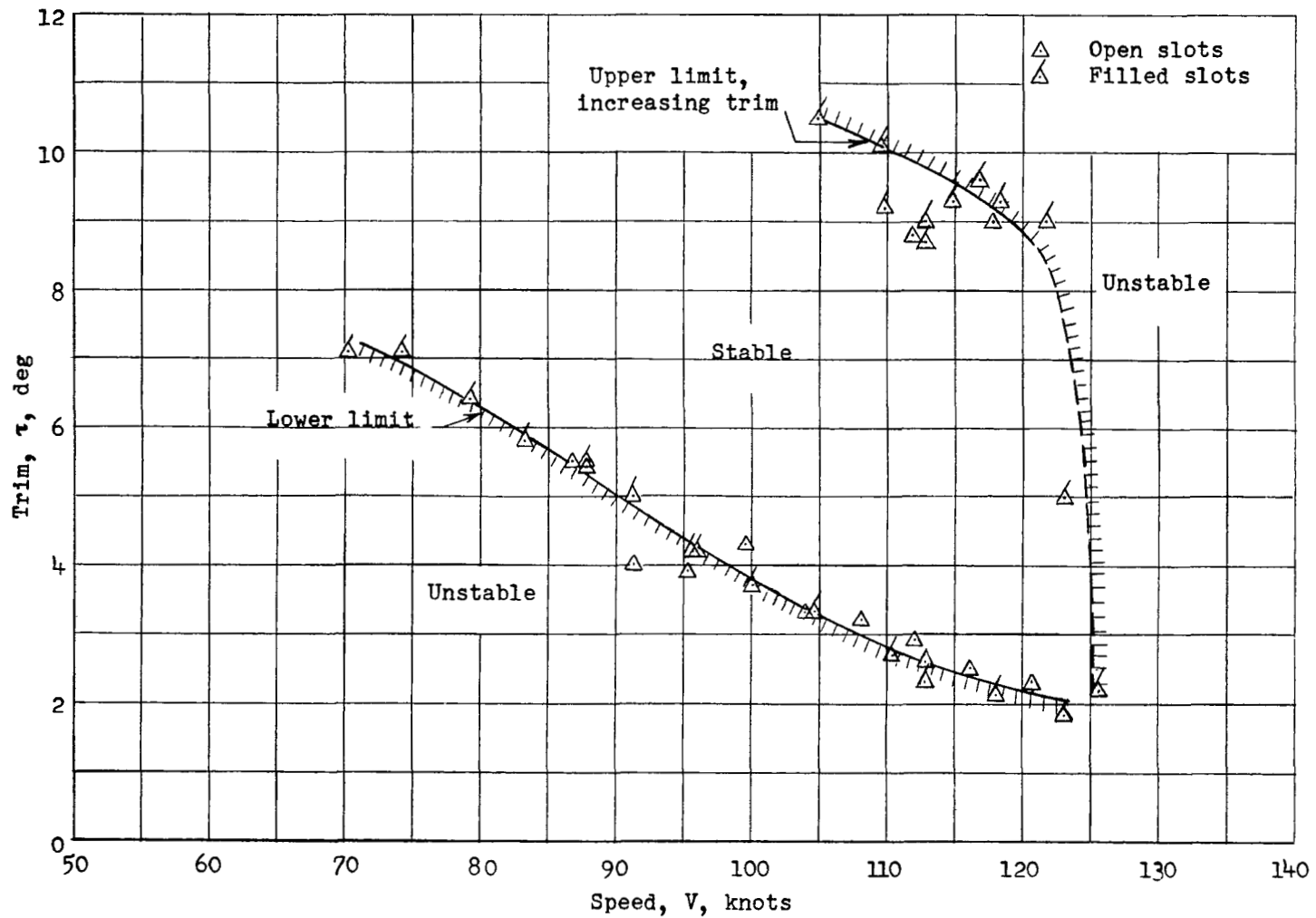
Basic model



Dam in longitudinal slots at step

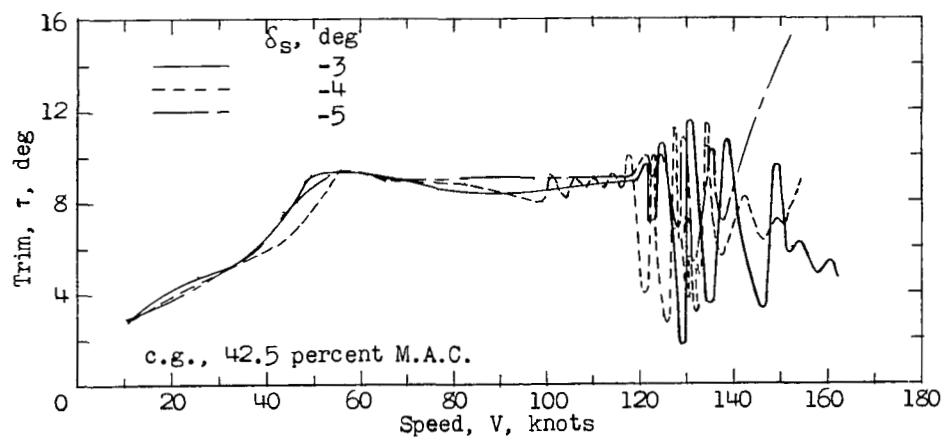
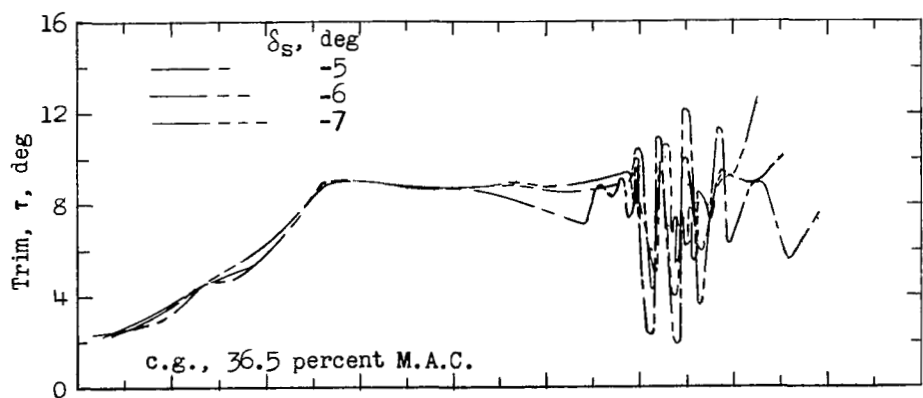
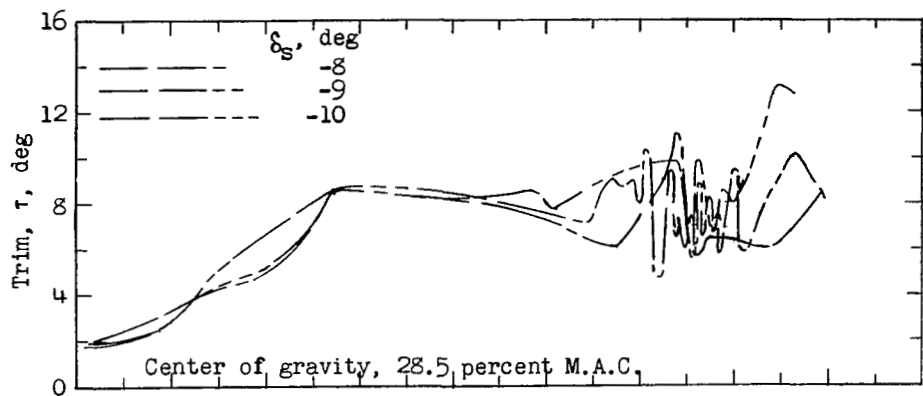
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Figure 14.- Underwater photographs of Langley tank model 314. Speed, 75 knots (full-scale); trim, 8.5° .



(a) Trim limits of stability.

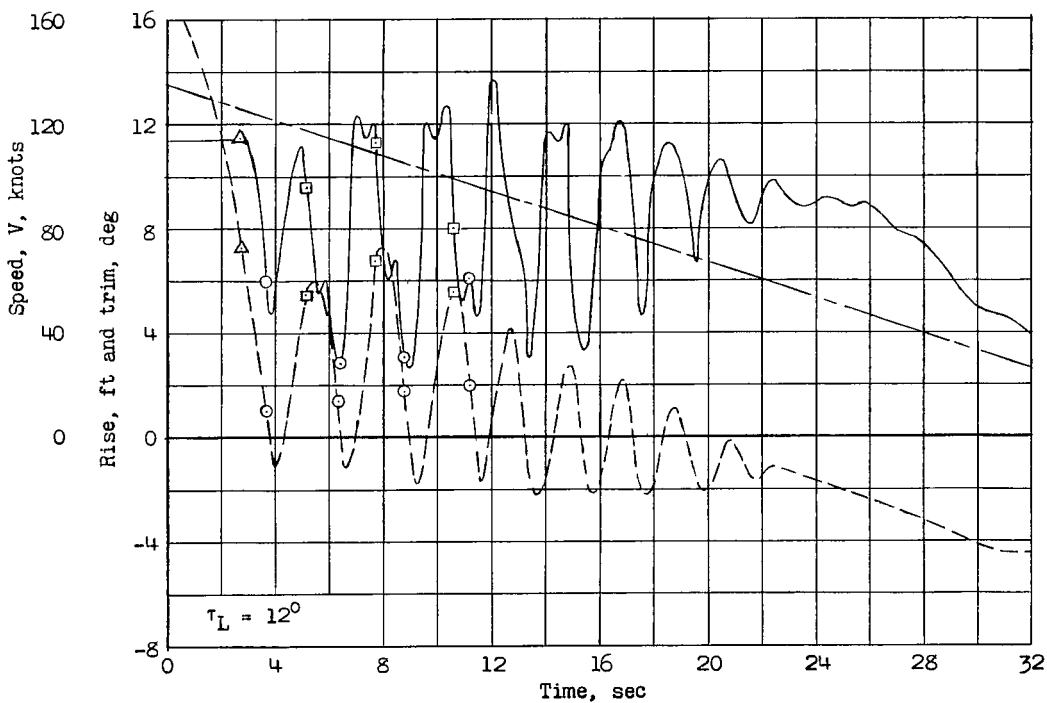
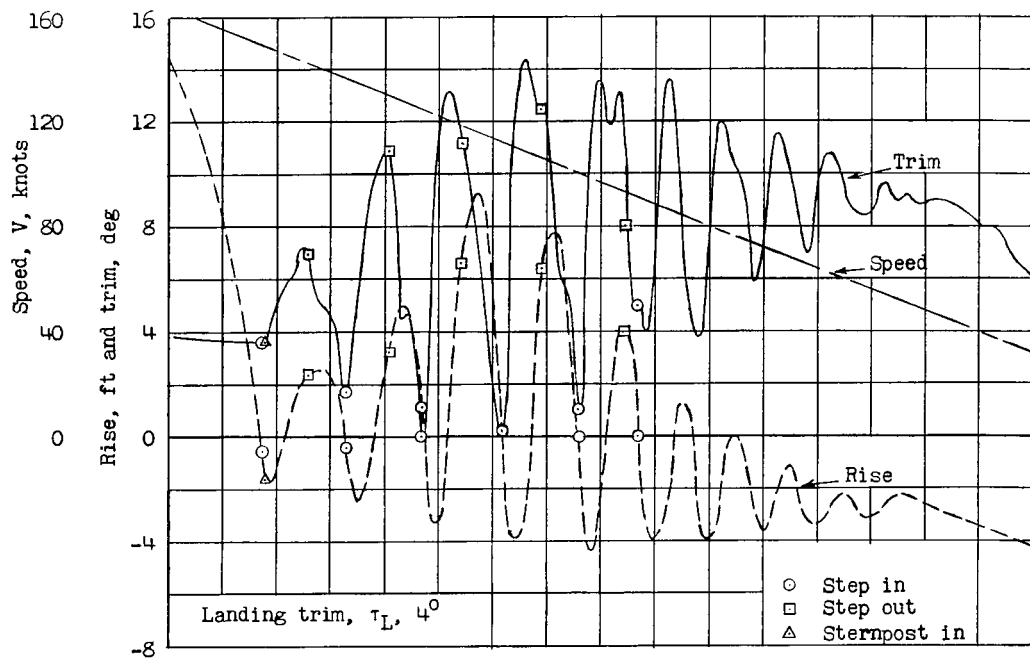
Figure 15.- Langley tank model 314.

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(b) Variation of trim with speed during take-off.

Figure 15.- Continued.

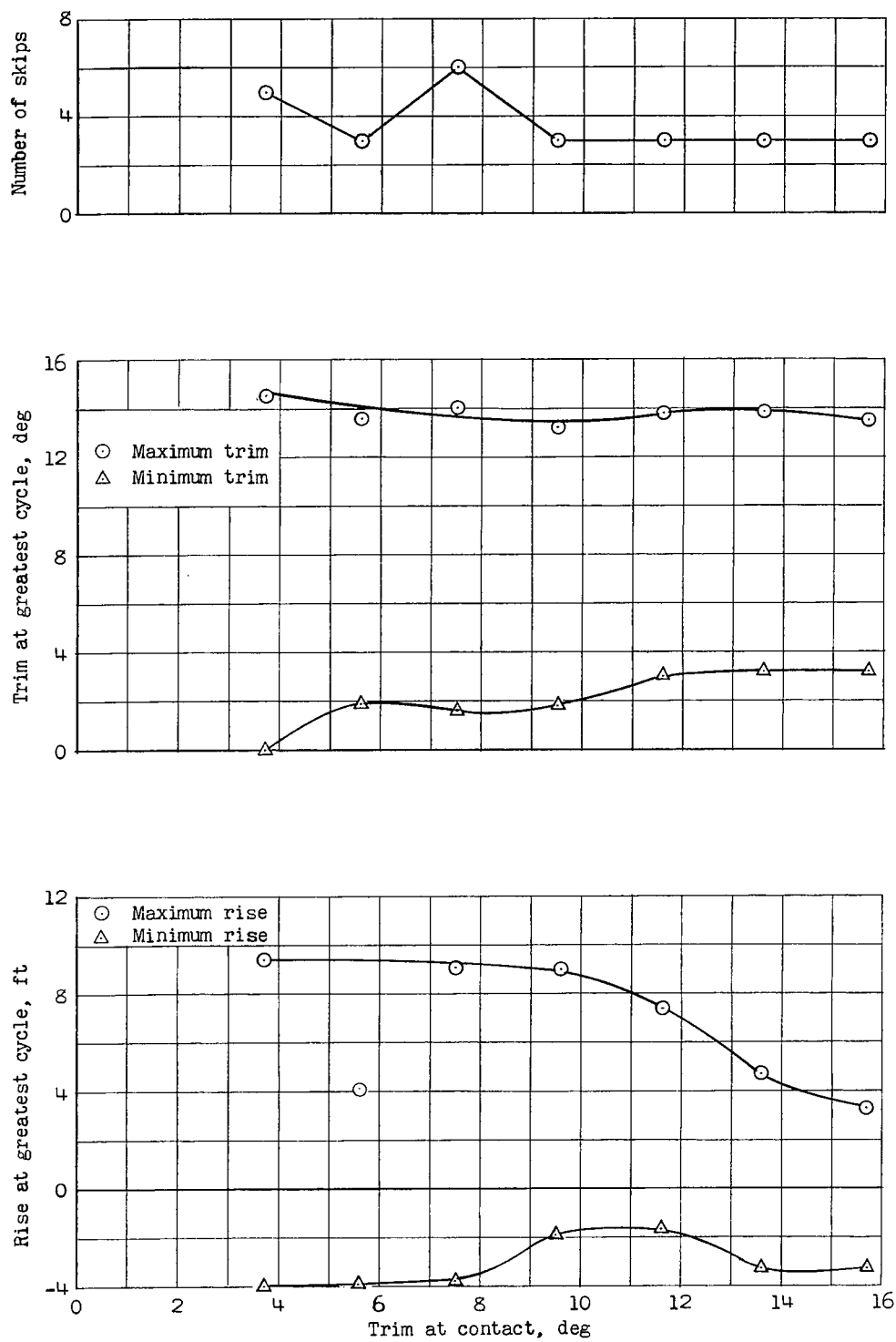
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(c) Variation of trim, rise, and speed with time during typical landings in smooth water.

Figure 15.- Continued.

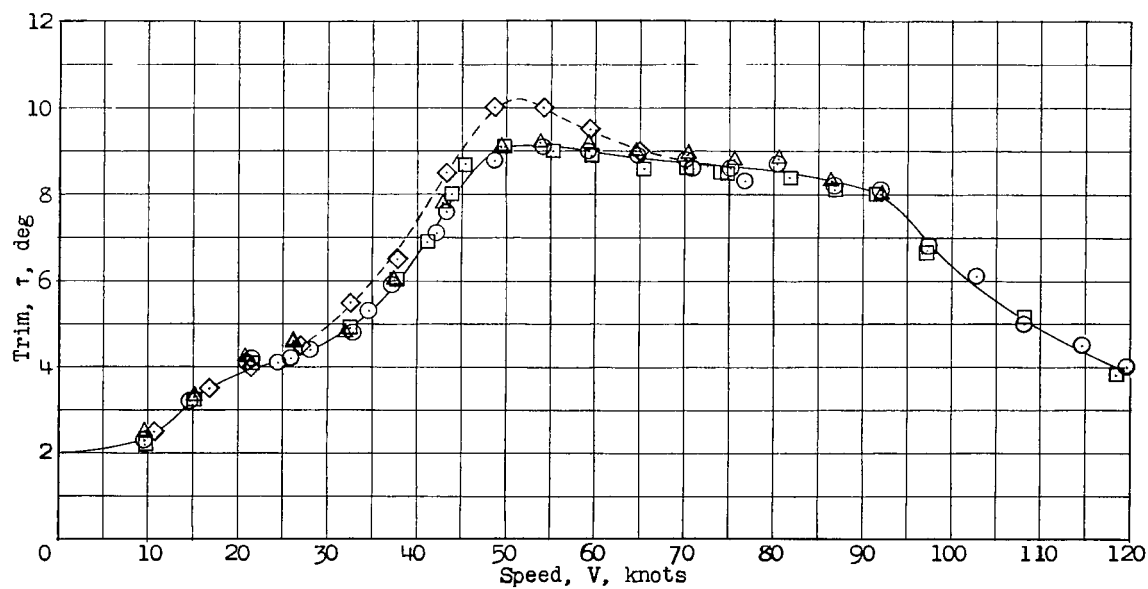
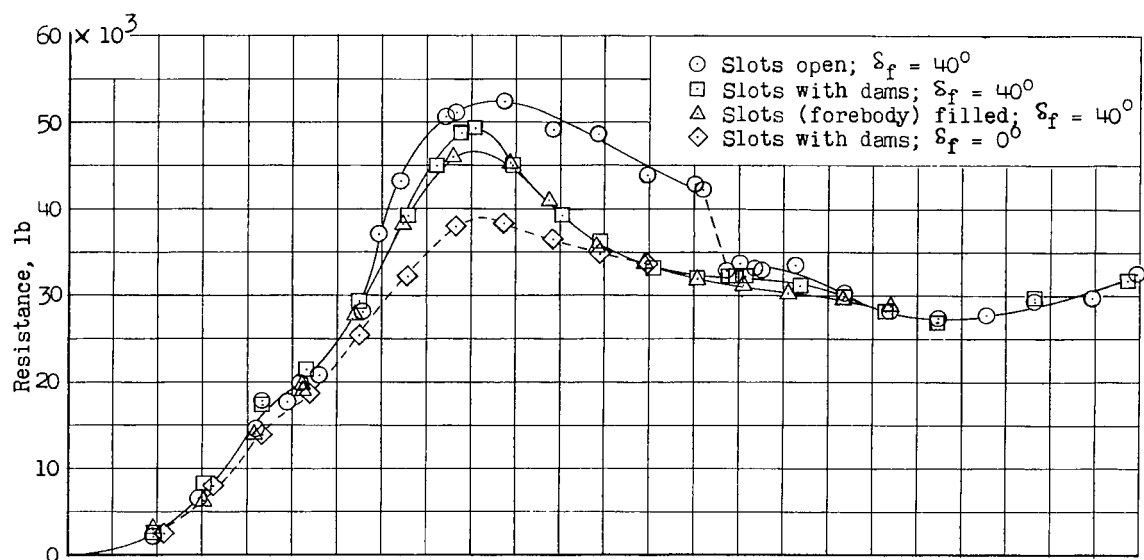
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(d) Landing stability characteristics in smooth water.

Figure 15.- Continued.

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(e) Variation of resistance and trim with speed.
 $\delta_s = 0^\circ$.

Figure 15.- Concluded.

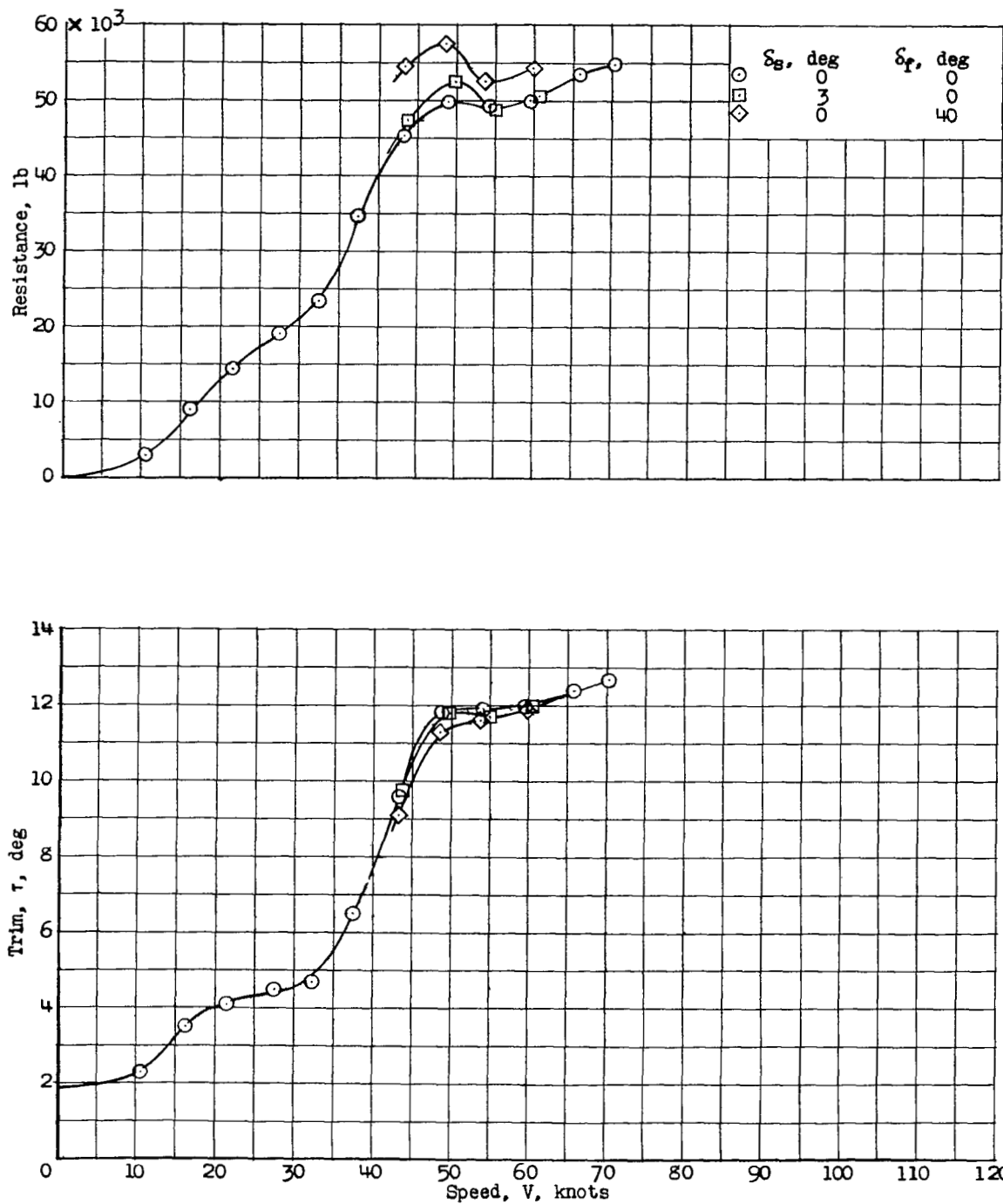
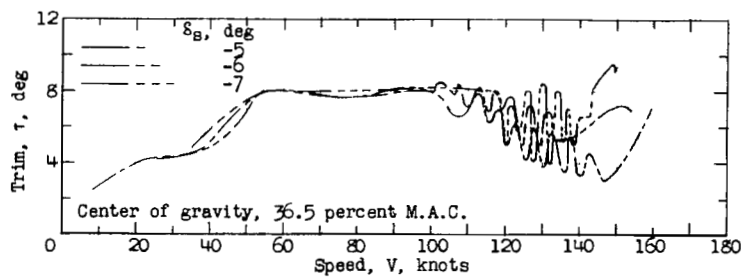
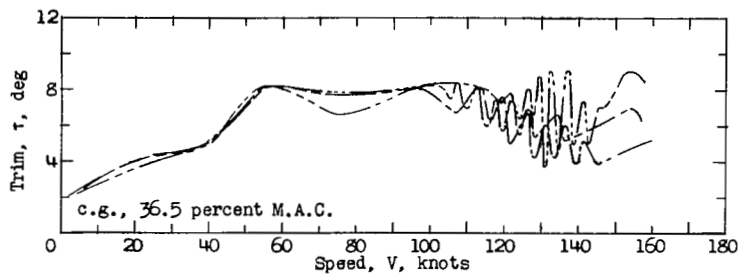


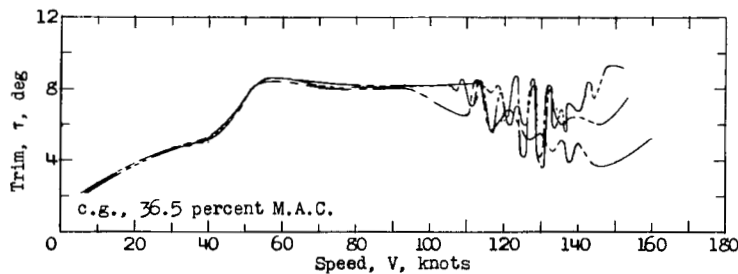
Figure 16.- Variation of resistance and trim with speed. Langley tank model 314A.

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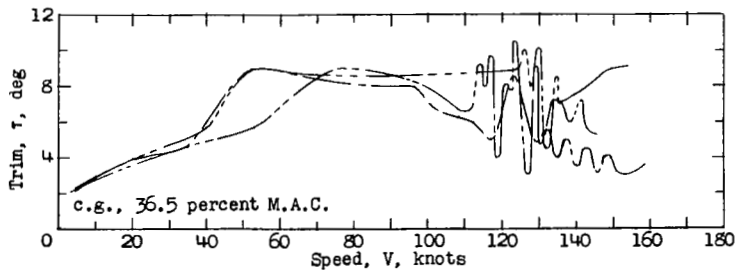
(a) Langley tank model 314B.



(b) Langley tank model 314B-1.



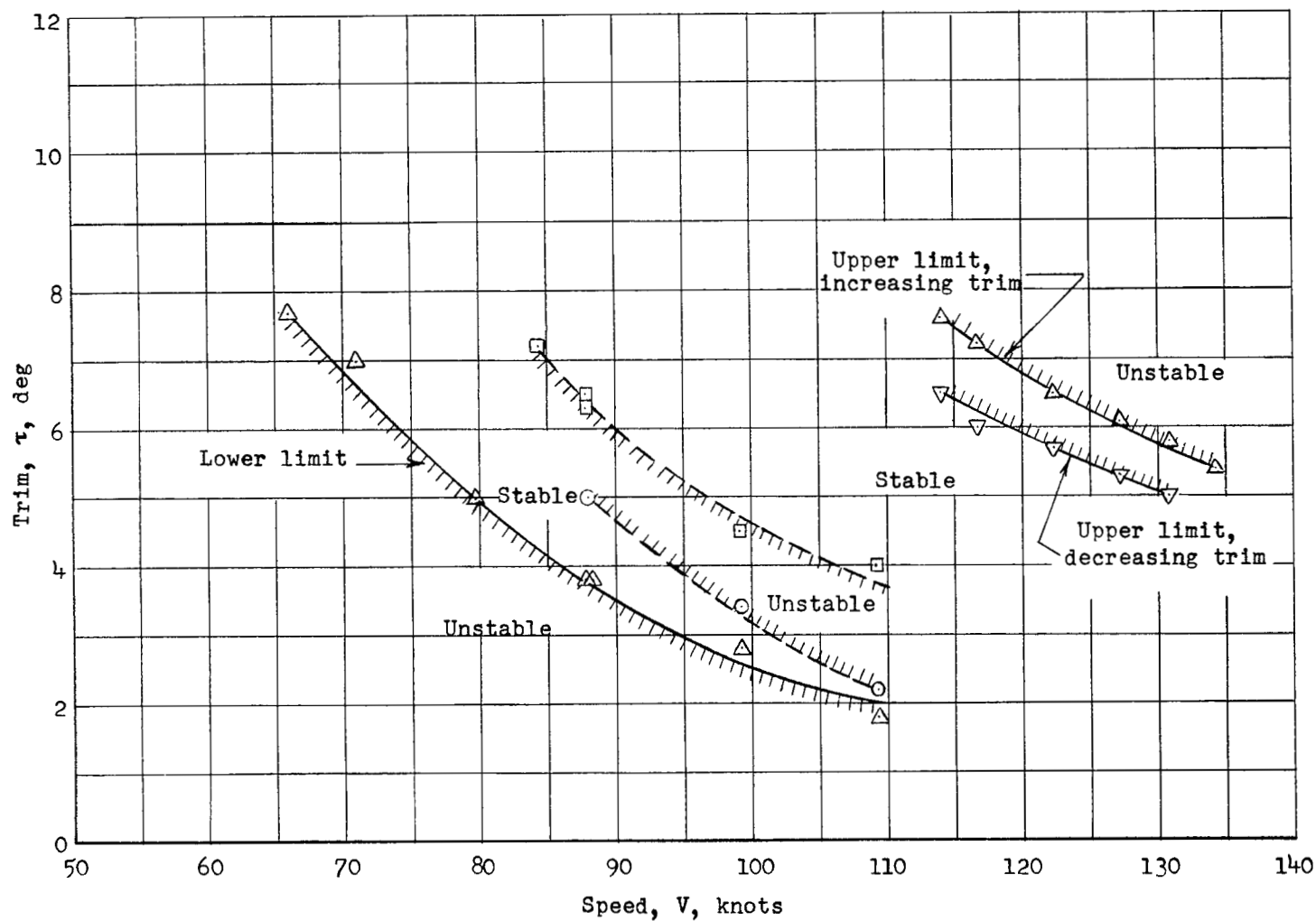
(c) Langley tank model 314B-2.



(d) Langley tank model 314B-3.

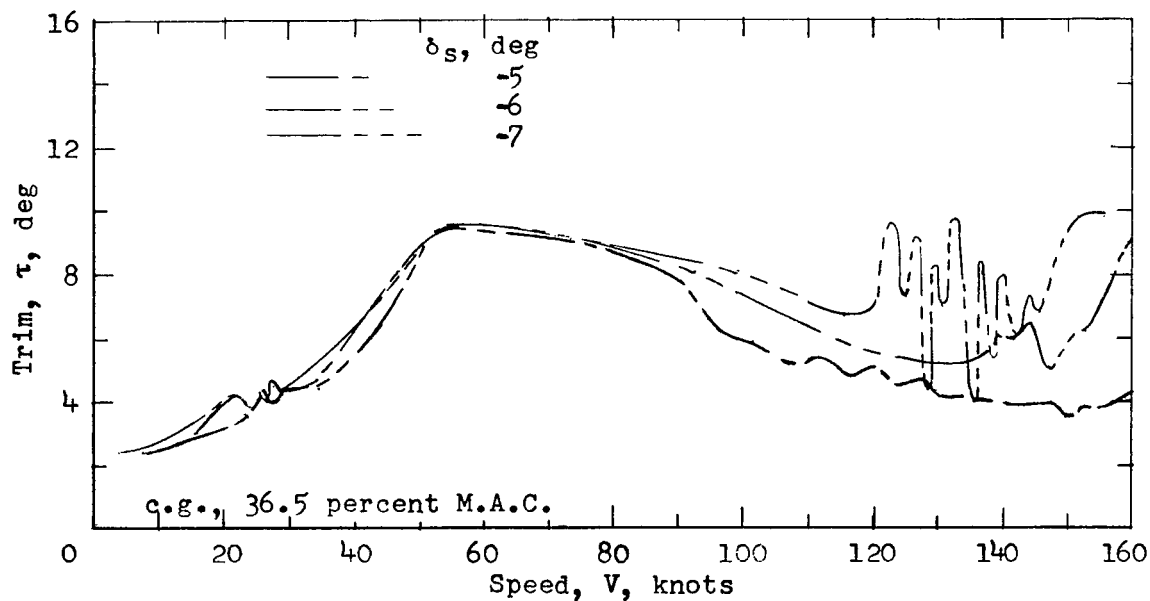
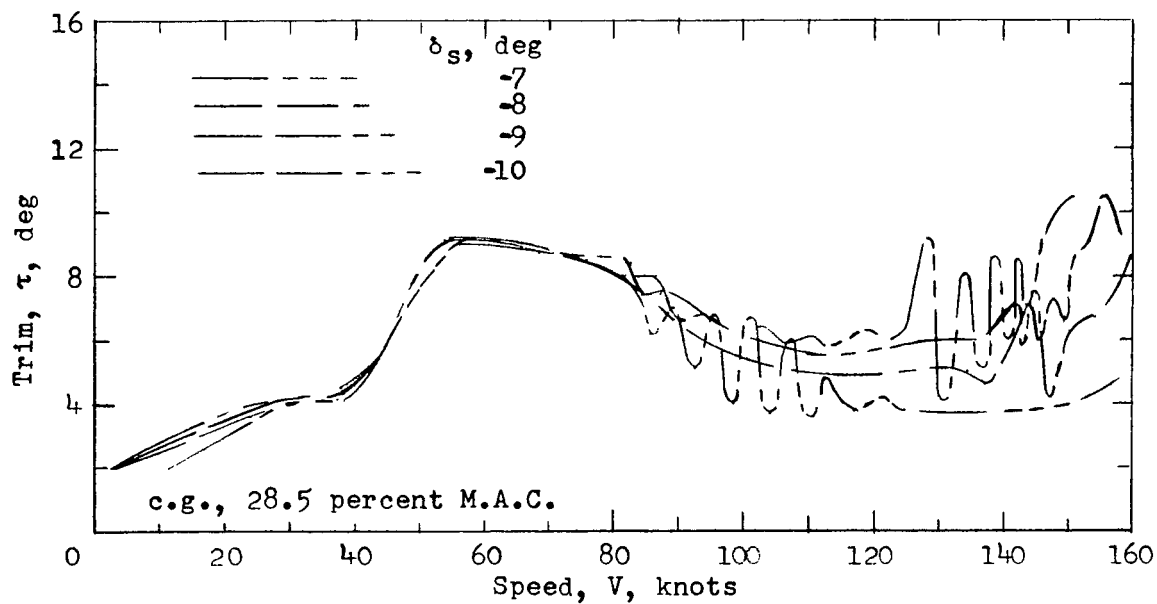
Figure 17.- Effect of spray strips on the variation of trim with speed during take-off.

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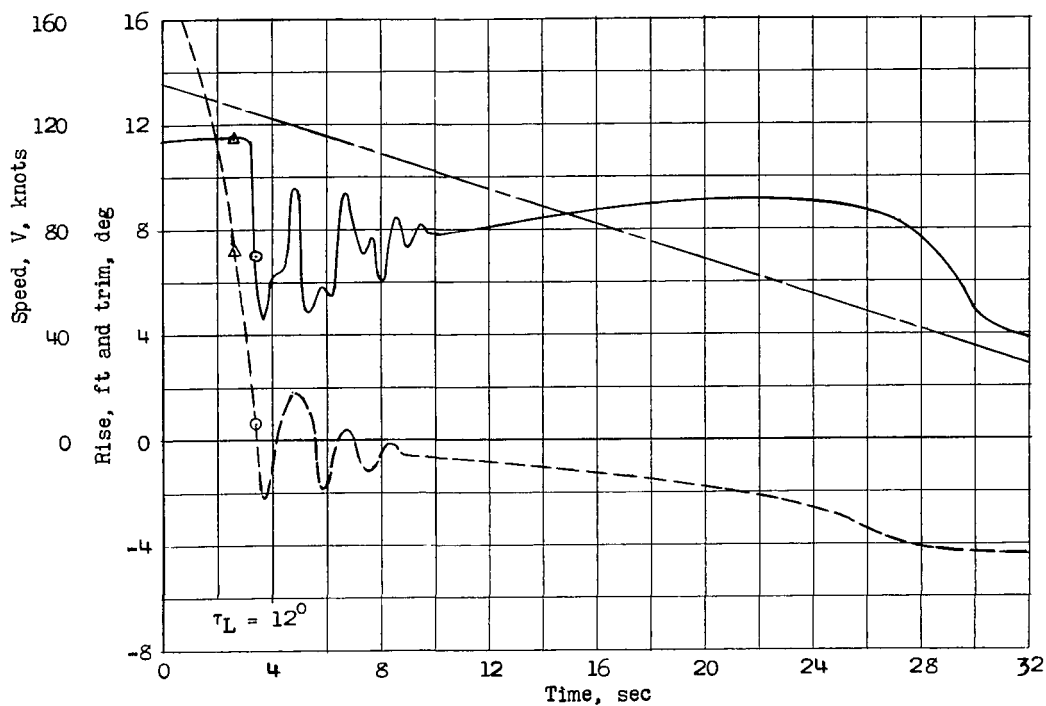
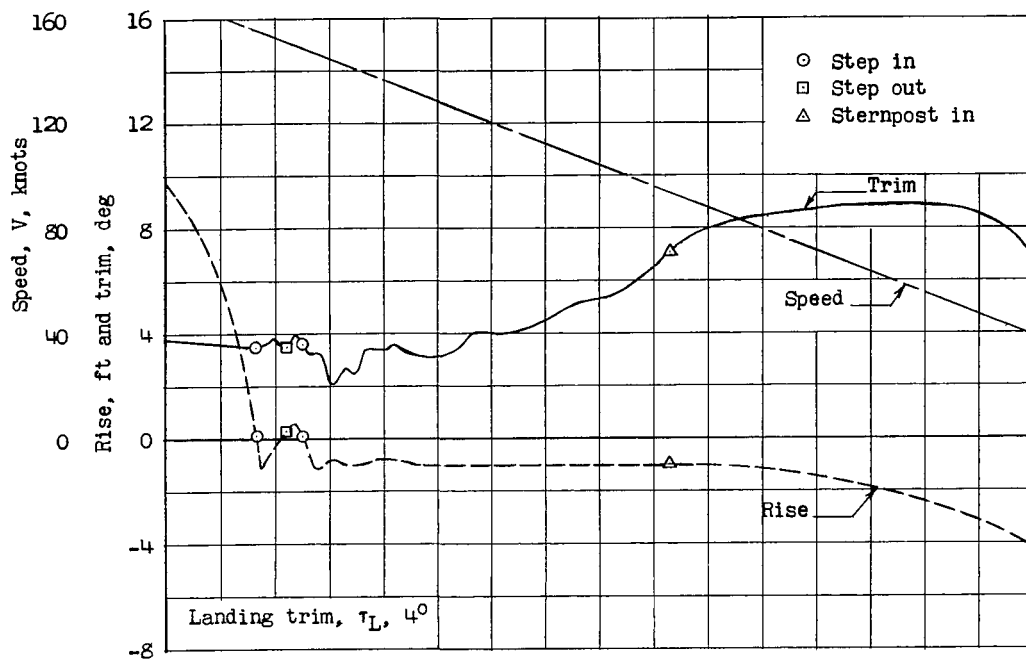
(a) Trim limits of stability.

Figure 18.- Langley tank model 314C.



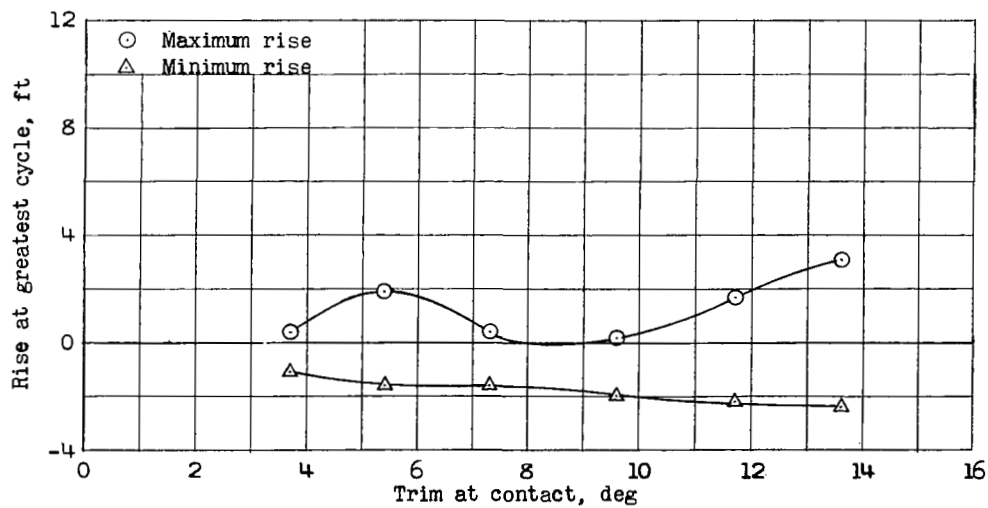
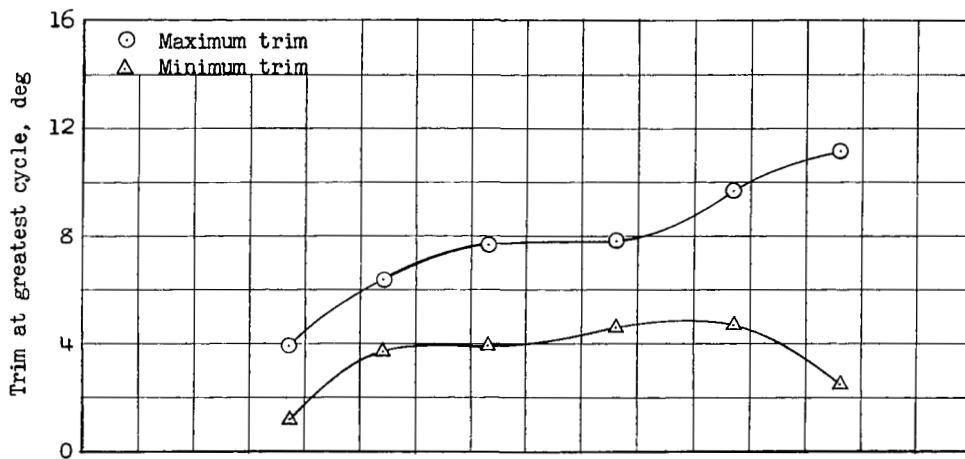
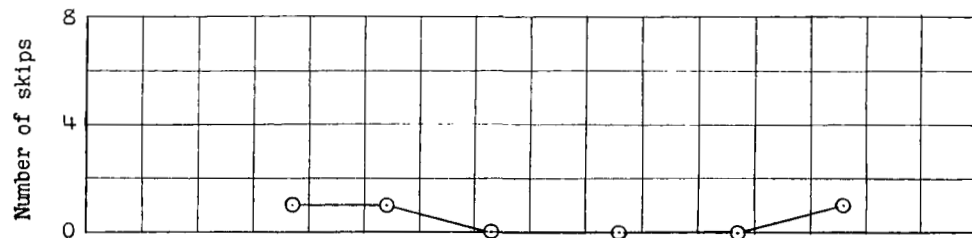
(b) Variation of trim with speed during take-off.

Figure 18.- Continued.



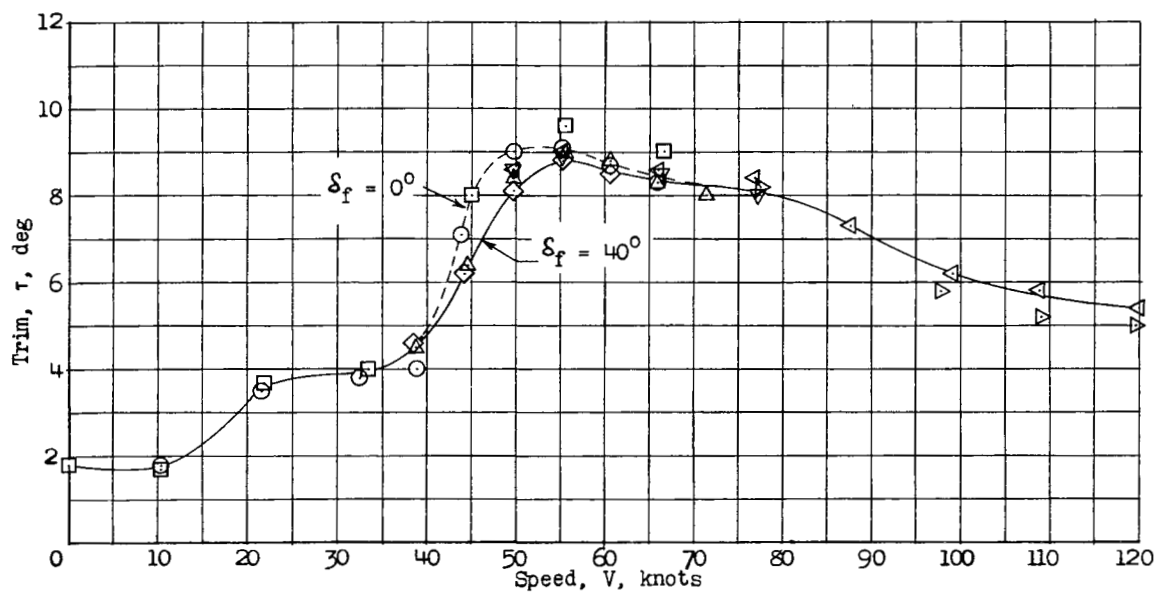
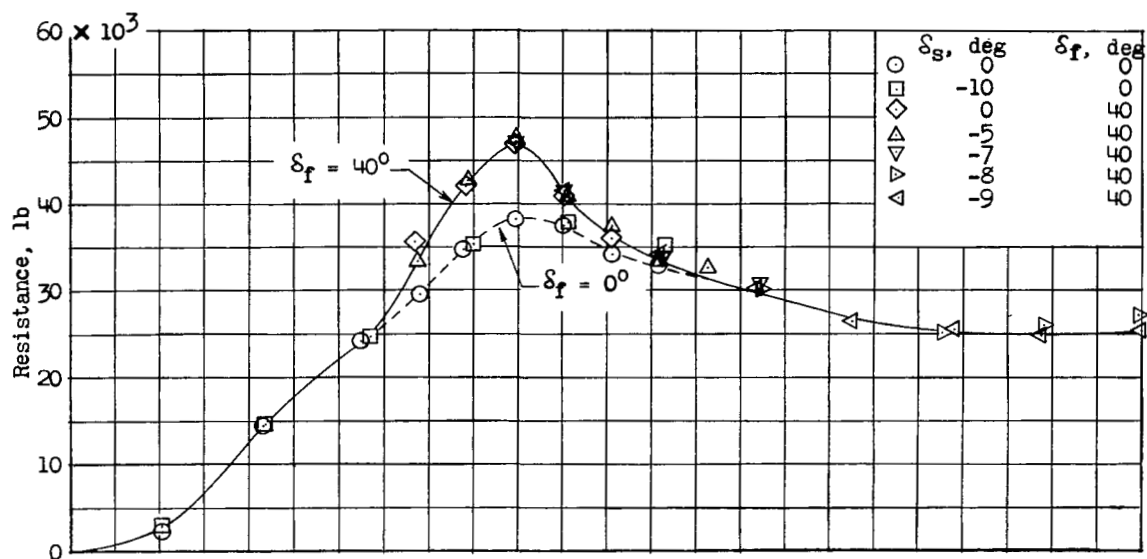
(c) Variation of trim, rise, and speed with time during typical landings in smooth water.

Figure 18.- Continued.



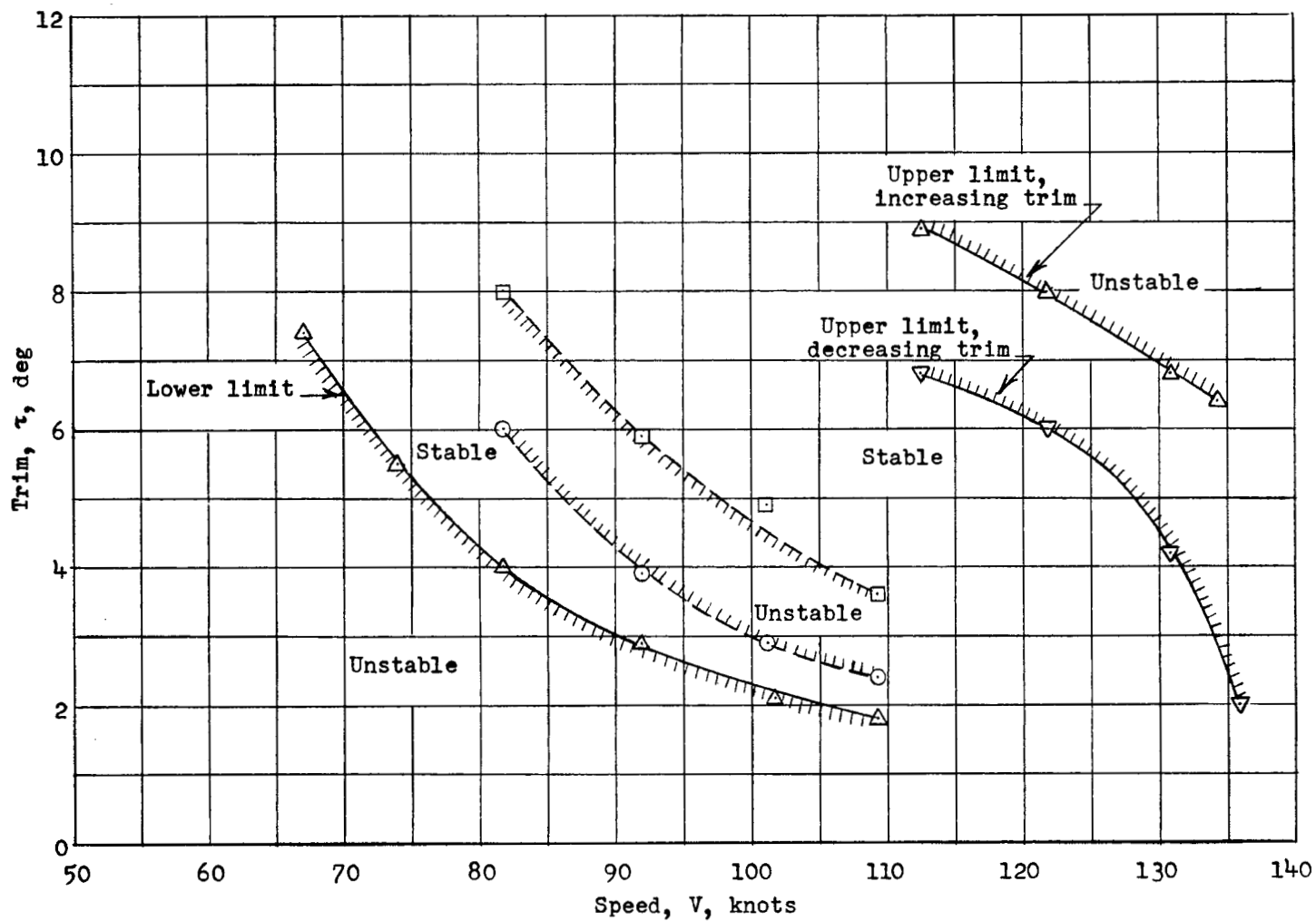
(d) Landing stability characteristics in smooth water.

Figure 18.- Continued.



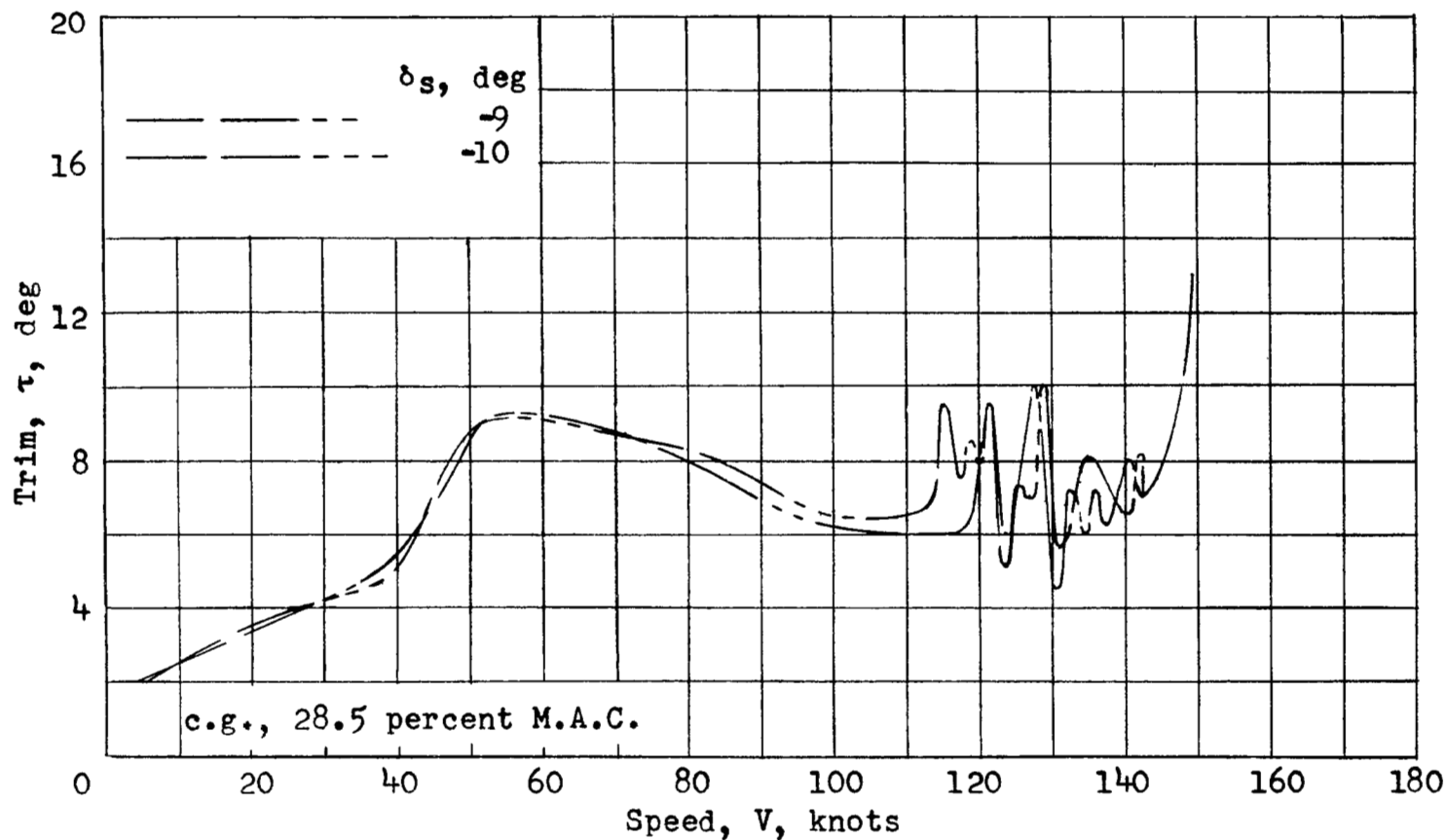
(e) Variation of resistance and trim with speed.

Figure 18.- Concluded.



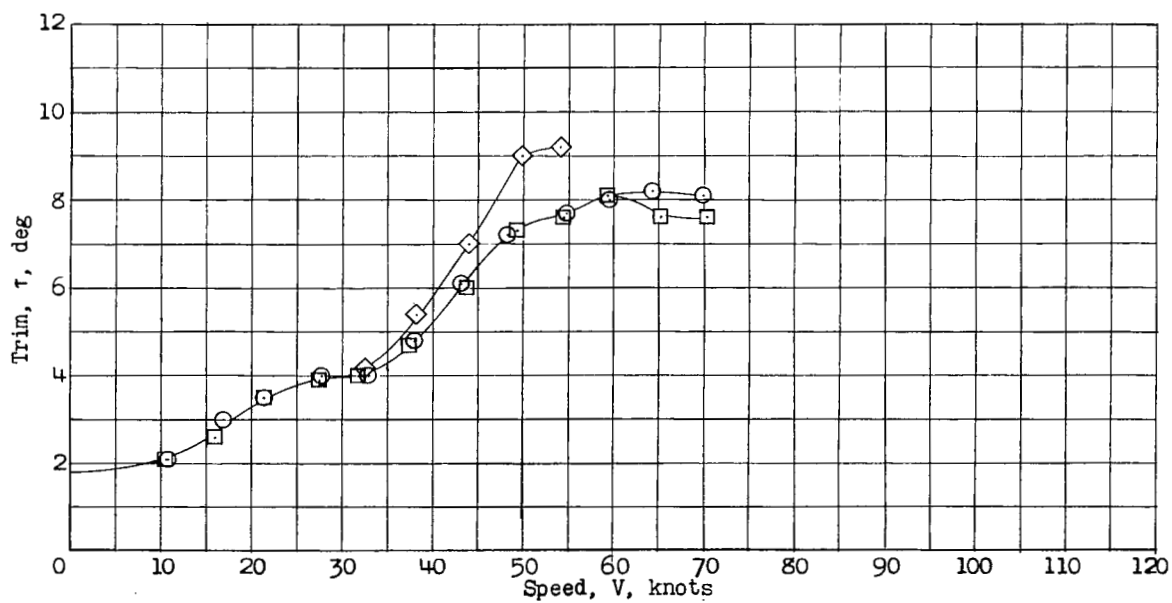
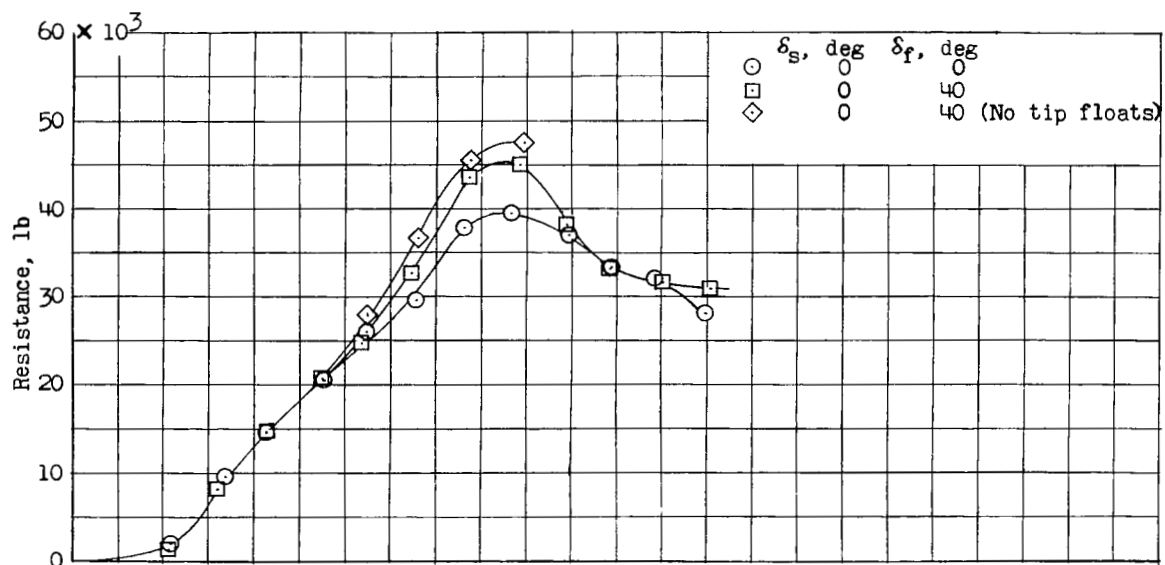
(a) Trim limits of stability.

Figure 19.- Langley tank model 314D.



(b) Variation of trim with speed during take-off.

Figure 19.- Continued.



(c) Variation of resistance and trim with speed.

Figure 19.- Concluded.

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